The Restoration of the Krishna Temple

Patan - Nepal

2015 - 2018

Kathmandu Valley Preservation Trust

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Neeta Das

With contributions by
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Sketch above of Patan Darbar Square by Alan G. Antony.

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Foreword

When in 1630 King Siddhinarasiṃha Malla embarked upon the construction of the Kṛṣṇa temple, he would have been a young ruler in his thirties, open to the suggestions and advice of the traders and travelling artists who would have helped him develop a new project, a temple whose form and scale was unprecedented in Nepal.

The result – as we see it today – is an elegant, palatial stone construction whose central tower, 21 gilded pinnacles, and 16 open air pavilions succeed as appearing suitable to serve as "the pleasure ground for Śrī Bālagopāla". So as the one inscription reads, and it continues, the structure might even be mistaken for Mount Meru, the Vindhyas, or Kailāśa. In a similar vein the king himself was often likened to Mount Meru.

Consecrated on the tenth day of the bright moon in February 1637 -- nearly four hundred years ago -- this temple remained miraculously intact until the recent earthquake in 2015. Although the temple did not fall at this time, interior structural disturbances had taken place which could only be understood upon close inspection and study in subsequent months. In retrospect, one can even say that the fact this venerable stone structure did not collapse in 2015 is nothing short of a miracle -- as so many grave structural weaknesses were present, the results of earthquakes in 1934 and 1833. These historical quakes had caused major disruptions on the second floor, the level of the Lord of All, Viśveśvara, who presides in his chamber directly below the shaft.

In 1984 the Nepal Heritage Society initiated its first proposal for the conservation of the temple; John Sanday Consultants prepared a "proposal for the conservation of the Krishna Mandir Temple" in 1987; and the Intach Conservation Centre of Lucknow sent

Sacred fire (*homa*) on August 24, 2018.
(*Courtesy of Department of Archaeology, Gaurav Khatri.*)

Opposite page
Armed Police Force, Nepal Army and Police and volunteers separating timber and bricks to sort out usable materials.
(*Photograph by Rohit Ranjitkar. May 01, 2015.*)

a mission in April, 1989. The findings were more or less confined to an observation of salt efflorescence and "gaps between the joints of the stones". Grouting was recommended to prevent future seepage of water and the leaching of the salt was to be treated with a "suitable chemical method". The large gaps that separated the corner stones and the heavy spalling at the bottom ends of the corners on second floor level were not properly understood as structural damage caused by earlier earthquakes. Under the guidance of Intach and employing the motto "restoration of faith" the Nepal Heritage Group undertook conservation work in 1998. Large gaps on the second floor were filled with thin slabs of stone and covered with mortar, mostly cement mortar. In the spirit of beautification, inconsistencies and surface irregularities were often covered up without understanding underlying problems.

By 2015, the grouting of the domes of the pavilions were not performing as expected. Water seepage had again become an all-pervading problem. The April 25, 2015 earthquake caused greater widening of the gaps and patches of mortar and plaster separated from the corner stones, now dislocated sufficiently to threaten

Minister of Tourism and Civil Aviation, Rabindra Adhikari, Director General of the Department of Archaeology Bhesh Narayan Dahal, Rohit Ranjitkar Country Director of the Kathmandu Valley Preservation Trust, Ajar Man Joshi former chairman of Lalitpur Chamber of Commerce and Tirtha Man Shakya former Chief Secretary of the Government of Nepal, August 24, 2018.
(Courtesy of Department of Archaeology, Gaurav Khatri)

imminent collapse. Even more frightening, several of the structurally necessary keystones above doorways to the sanctum had disintegrated from interaction with mortars and salts.

In the aftermath of the 2015 earthquake, the team of the Kathmandu Valley Preservation Trust was confronted this architectural repair with great trepidation – largely inexperienced in the consolidation of stone architecture and especially on this scale. A project report of the Lalitpur Heritage Group had been prescient in quoting Saphalya Amatya's 1989 remarks that emphasized "that the restoration work presented a stiff challenge with grave implications if things went wrong". Subsequently he advised approaching UNESCO to undertake the work and calling for international financial and technical support.

In August 2015 the burden of this "stiff challenge" was somewhat lightened when the possibility of financial support became available from the Gerda Henkel Foundation, funding for technical support from a leading expert in conservation of the region, in this case Neeta Das from Kolkata. The team planned to engage an Indian team with relevant experience to undertake the specialized work, but unfortunately, the impossible political situation following the quake precluded any collaboration with the neighboring country. In a painful, yet ultimately and surprisingly successful process, the KVPT's small team of Nepalese architects, engineers and stone masons slowly learned to deal with the special characteristics of the building and its stone structure. The "stiff challenge" was in fact met with patience and time. This process took two years, for example, to be able to design and implement the correct type of structural shoring to replace the four bearing corner stones. Further work such as the repair of lintels and columns, the grouting of joints with lime (imported from Italy via New Delhi), and the cleaning of the pinnacles was successfully managed with further assistance and technical support of a team from the University of Applied Arts Vienna as well as the guidance of the consultant from Kolkata.

Completed work on upper levels allowed the scaffolding to be removed in June- July of 2018; repairs at the base of the temple concluded the ambitious project just in time for birthday celebration of Kṛṣṇa in 2018. An historical extant inscription aptly praises the building as "Vaikuṇṭha's equal on earth" - the abode of Viṣṇu, of liberation.

Homage to Gopāla
Creating all as Brahmā, preserving it as Hari, taking the form of Rudra at the end of the Age - homage to you who manifest as three.

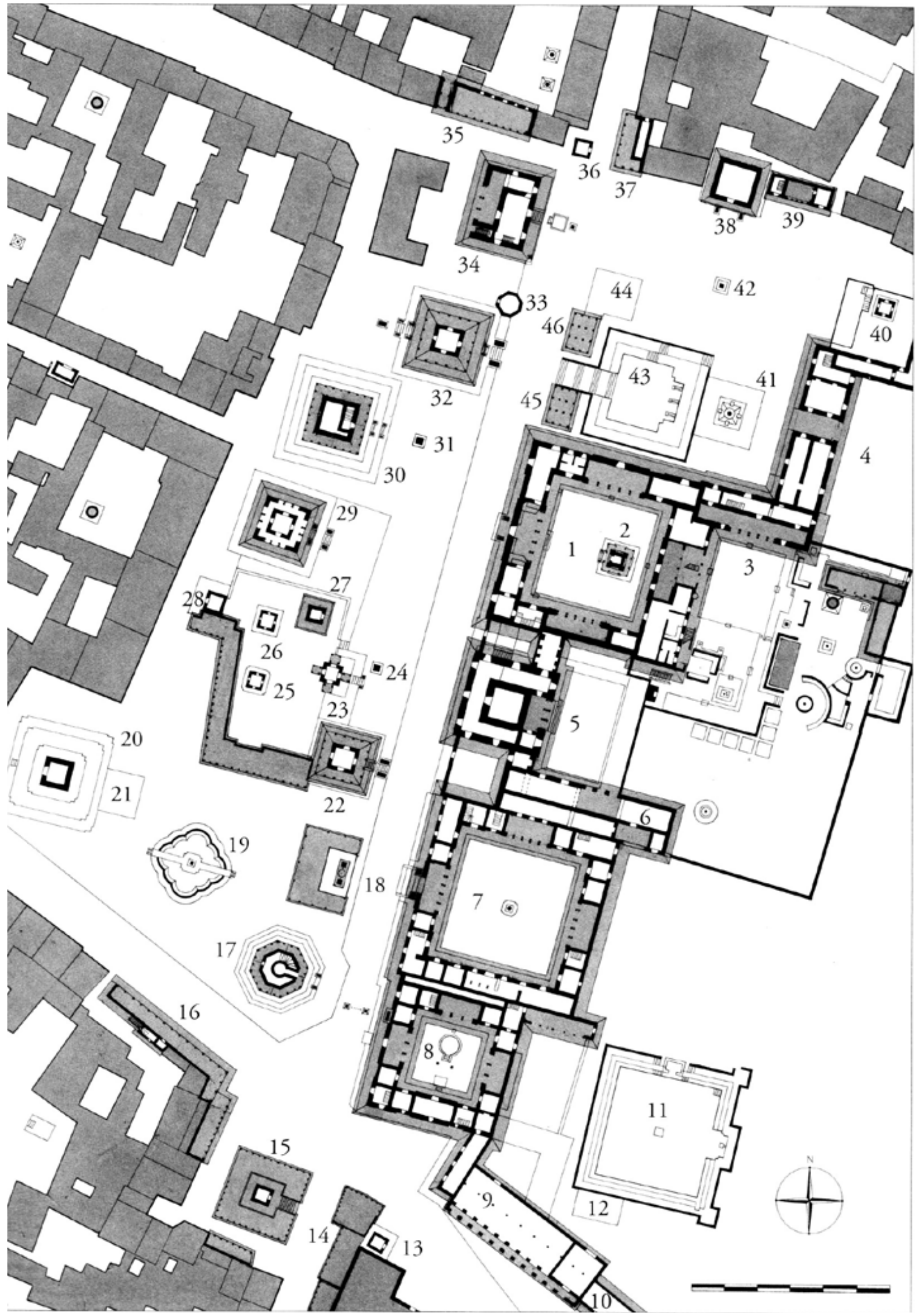
With this initial dedication of the inscription we return the "pleasure ground of Bālagopāla", the young cowherd, to his devotees.

Patan
Kṛṣṇa Janmaṣṭamī, Bhādra 17, 2075 VS
September 2, 2018

Niels Gutschow - Rohit Ranjitkar - Erich Theophile

Opposite page
The four restored corners (NE, SE, SW and NW respectively) of the second floor.
(*Photographs Ashesh Rajbhansh, September 17, 2018*)

Back opposite page
Water color by Henry A. Oldfield, in 1855.
(Source: British Library.)



Patan, Darbār Square
1 Keśava Nārāyaṇa Cuka, originally the site of an early palace, the present structure replaced an early 17th-century quadrangle in the 1730s;
2 Maṇikeśava (or Keśava Nārāyaṇa) temple, with 15th-century stone columns;
3 North-East wing with fragments from the 16th century; 4 Northern wing, probably built by Bahādur Śāha in the 1790s; 5 Three-tiered Degutale temple, first built in 1661, collapsed in the 1934 earthquake, simplified reconstruction;
6 Taleju temple, three-tiered octagonal tower on a five-storeyed substructure, originally erected by Śrīnivāsamalla in 1671; 7 Mūcuka, originally constructed by Śrīnivāsamalla in 1666 with the shrine dedicated to Yaṇtāju, the personal deity (iṣṭadevatā) of the kings; a three-tiered esoteric shrine tops the gap between the Mūcuka and Sundaricuka; 8 Sundaricuka, probably first erected by Siddhinarasiṃhamalla in 1647 together with the Tusahiti step-well, replaced by Viṣṇumalla in the 1730s; 9 Koṭ building, erected in the 1820s, porch added in 1910; 10 Koṭpātī, a long arcade, named after the Koṭ; dismantled in 2009;
11 Shrine of Duimāju, established in 1588 by Purandarasiṃha;
12 Bhaṇḍārkhāl tank, constructed by Siddhinarasiṃhamalla in 1647;
13 Bhasmeśvara, a late 17th-century śikhara temple that collapsed in 1934, now a simple domed structure; 14 Ādinārāyaṇa temple, erected in 1569 by Uddhavaśivasiṃha, collapsed in 1934; 15 Umāmaheśvara, a late 17th-century śikhara temple, collapsed in 1934, two storeys survive under a bell-shaped top;
16 Lampāṭī, constructed in 1678, upper storey renewed in 1994;
17 Octagonal śikhara temple, dedicated to Kṛṣṇa by Yogamatī in 1723;
18 Large bell on a high pedestal, dedicated to Taleju in 1737; 19 Fountain, established in memory of the Bara Mahārāṇi who died on February 11th 1905;
20 Three-tiered Viśvanātha temple, established in 1678 by Bhagīratha Bhaiyā, collapsed in 1934, the sanctum of the three-tiered temple survives with a dome;
21 Dabu, platform for the permormance of ritual dances; 22 Three-tiered Hariśaṅkara temple, built by Rudramatī in 1706; 23 Narasiṃha temple with śikhara tower, built in 1589 by Purandarasiṃha; 24 Pillar with Yoganarendramalla, 1693; 25 Temple dedicated to Buddha, established 1972;
26 Temple dedicated to Viṣṇu, 1970s; 27 Two-tiered Nārāyaṇa temple, 1652;
28 Domed Mahādeva temple, 19th century; 29 Two-tiered Cārnārāyaṇa temple, 1566; 30 Kṛṣṇa (Bālagopāla) temple with śikhara tower, 1637;
31 Garuḍa pillar, 1637; 32 Two-tiered Viśvanātha temple, 1627;
33 Maṇigupha, 17th century; 34 Three-tiered Bhīmsen temple, 1680;
35 Lakhe Śreṣṭha Āganchen, 17th century; 36 Kopeśvara temple, 1893;
37 Sarasvatīphalcā, early 17th century, dismantled in 1992, rebuilt with reduced width in 1993; 38 Maṇigaṇeśa temple, dismantled in 1975 and rebuilt in the same year; 39 Ayaḥguṭhi sattal, 17th century, collapsed in 1998, reconstructed in 2002; 40 Āganchen of Rājopādhyāya and Mahādeva temple, also with Gaṇeśa, dated 1438, and Lakṣmīnārāyaṇa, dated 1415;
41 Maṇicaitya, 16th century; 42 Pillar, dated 1940, commemorating the 1934 earthquake; 43 Maṇihiti, 17th century step-well with fragments of the Licchavi era and inscription dating from 570; 44 Dabu, platform for the performance of ritual dances; 45 Maṇimaṇḍapa, 14th-century central pillars, rebuilt in 1701; 45 Maṇḍapa, 17th century.
Sources: Hagmüller 2002, p. 28, compiled by Götz Hagmüller from various sources, drawing by S. Rajbhandari, 1996

Patan Darbar Square, World Heritage Site.
(Source: Niels Gutschow. Architecture of the Newars. 2011.)

Introduction

Until I reached Patan, Nepal to me was a neighboring country where Indians went for their honeymoon, buy 'imported' items, or to visit Pashupathnath temple. But the Patan Darbar Square took my breath away with the exuberance of workmanship in wood and terracotta. The Krishna temple, which we had gone to inspect, stood amidst this fantastic background of ground hugging 'pagoda' now referred correctly as 'tiered temples' often with 'pyramidal roofs' or Newari *degah* and ornate palaces. Sounds of *kirtan*, devotional singing from the Krishna temple, filled the Darbar Square and reminded one that Nepal was a Hindu state.

It felt strange to be in another Hindu country, but the humble *namaste* of the locals also made you realize how much of our culture we, in India, were losing out. Unlike India, Nepal still uses the Hindu calendar. Its geographical location greatly reduced the invasion of foreign rules like the Mughals and the British, and therefore prevented major changes in their culture. India was probably the only country that had the greatest influence on Nepal.

Geographically Nepal can be divided into three regions from north to south: the Himal, Pahar, and Tarai. Himal, is the high mountain area, sparsely populated by Buddhist of Tibetan origin. Tarai region has people mostly of Indian origin speaking Maithili, Bhojpuri, and Awadhi. The name 'Nepal' was traditionally applied only to the Kathmandu Valley in the Pahar area and is linked to the Valley's most ancient inhabitants, the Newars.

By the 5th century AD Nepal was documented some time after the establishment of a centralized state by the Licchavi rulers, possibly a branch of the Licchavi rulers in India. This was followed by the Gupta rule in the seventh century with a return of the Licchavi rule soon after. As Gupta religious art declined in India, it reached Nepal.

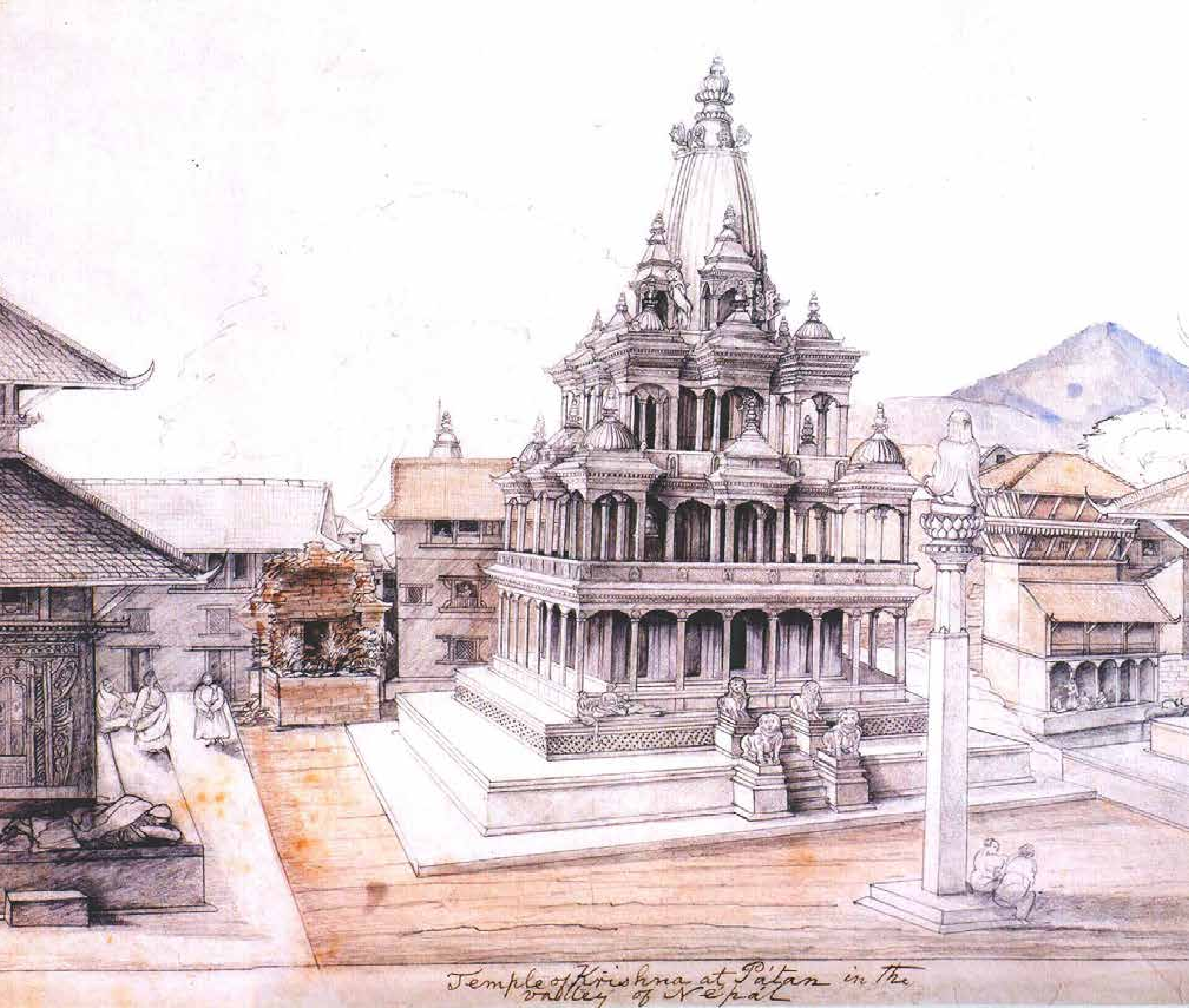
The ninth to the twelfth century saw strong links with the Pala kings of India, who followed the Tantric school of Buddhism from Bengal in India. After the Muslim invasion after the 13th century India and the destruction of monasteries, many monks and artists fled to Nepal. The Malla rulers who followed in the 13th century were also Buddhist and had connections to Maithili, India. However, in 1370, the Malla dynasty was strongly established by Sthiti Malla, a Hindu noble, from Maithili. He codified Hindu laws of caste and conduct brought from India and it was at this time that 'Newari' became the literary language.

As time went on, later Malla rulers developed their own independent kingdoms most prominent being Kathmandu, Bhaktapur, and Lalitpur (Patan). Each kingdom had it's own city center or the Darbar Square which housed their palaces and showcased their temples. These city centers have the richest collection of art and architecture which has earned them the status of 'World Heritage Sites'.

With rulers being Hindu and Buddhist alternately, both religions flourished and sometimes fused together and resulted in unique marriages and forms. Locals believe that Buddha was a Newari and some Gods like Matsyendranath who was bought from India, are Hindu as well as Buddhist. They also feel the oppression of the Hindu rulers from India might have resulted in the suppression of the Buddhist and the gradual integration of the two cultures . Whatever the reason, it is this integration which has given birth to a 'new' form of architecture that is unique to 'Nepal', and the Krishna temple is an outcome of this culture.

Top
It is common to see Buddha being worshipped alongside Hindu deities.

Opposite page
The restored Krishna Temple.
(Photograph by Raju Roka October 15, 2018.)



Chapter 1:

Historical Background

The Krishna Temple on first impression looks like a north Indian Hindu temple with a parabolic *shikara garbha griha,* with an ambulatory, carved statues of Hindu gods and goddesses, common temple items like vermillion and flowers adorning the idols, incense sticks, and the singing of devotional songs in the cramped colonnaded space in front of the *garbha griha.* It is then one starts feeling the absence of the *mandapa* that preceded the *garbha griha* in Indian temples for these activities. Further, the climb up the second floor to the Shiva level, confirms its departure from an Indian temple as a double tiered temple was seen in Jain temples in India but was almost unknown in Hindu temples.

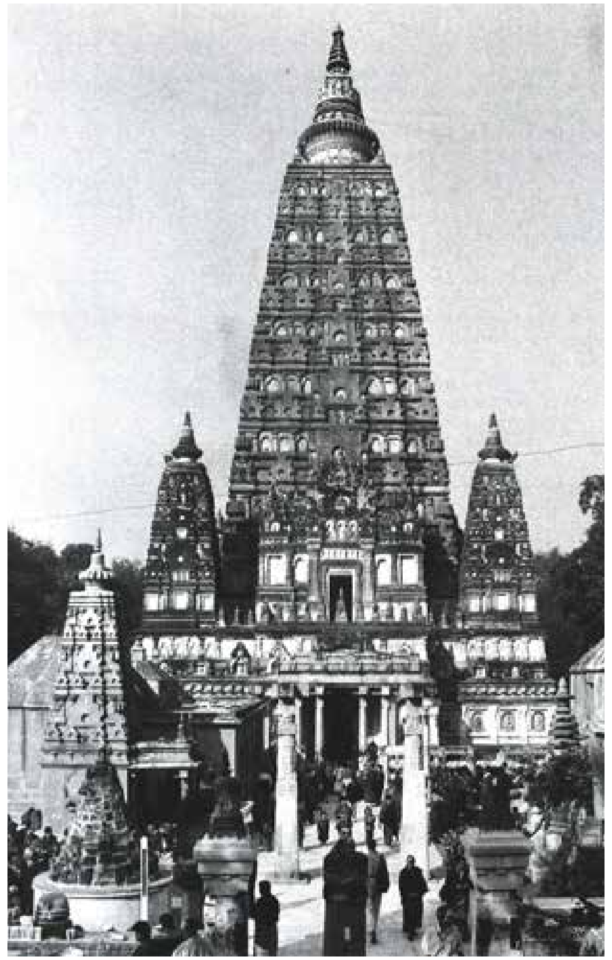
So to understand the Krishna Temple one had to start from the beginning again. Consecrated on 23rd February 1637, the Krishna Temple was built by the King Siddhi Narsimha Malla in the Patan Darbar Square. The invasion of India by Muslim rulers saw a break in the construction of temples in India. However, temple architecture flourished in Nepal all through this period. By the seventeenth century, when Krishna temple was built, temples were made either in the tiered style with pyramidal roofs called *degah* called *devala* or in the *shikara* style. To look for the stylistic development of the Krishna Temple, one either had to look to pre-Muslim India or the *shikara* temples of Nepal.

One is surprised to find almost no temple in India that could have influenced the construction of the Krishna Temple. If one looks to Nepal, three temples were built in the *shikara style*; the old shrine of Pashupatinath (8th-13th century) with two miniature shrines, one with a *shikara* and one with a pyramidal roof, the Narasimha Temple (1589) in the Patan Darbar Square; and the Mahabaudhha Temple (1601) in Patan.

One would have to conclude then that Krishna Temple departed from the basic form of a North Indian temple, borrowed the tiers from the Mahabaudhha and other Newar temples, and immortalizes the experiments of the brick Narasimha Temple in stone. The only part in question now are the two bay colonnaded ambulatories that make it unique in form and expression. Niels Gutschow in his book *Towers in Stone*, gives a detailed description of the stylistic development of Krishna Temple in which he writes; "The Nepalese builders somehow create the opposite (of a solid mass to replicate a mountain) as they conceal the great trunk of the *sikhara* structure behind lighter arcades with screened parapets." He further adds that this results in the temple looking lighter and "which enthralls us in the airy structure of the Krishna Temple." Gutschow discusses this, and other similar temples, in the same book in great detail.

Left
Padmapani temple, Alko Hiti, built around 1600AD.

Opposite
19th century sketch of the Krishna Temple by Rajman Singh. (*Source: History of Kings of Nepal. A Buddhist Chronicle. Edited by Niels Gutschow. 2015. Pg.129.*)



Left
Mahabodhi Temple, Bodh Gaya as seen from the East.
(Source : Tower in Stone by Bijay Basukala, Niels Gutschow, and Kishor Kayastha. Pg. 9.)

Center
Model of the Mahabodhi Temple that was carried to Patan.
(Source: Towers in Stone, by Bijay Basukala, Niels Gutschow, and Kishor Kayastha. Pg. 8.)

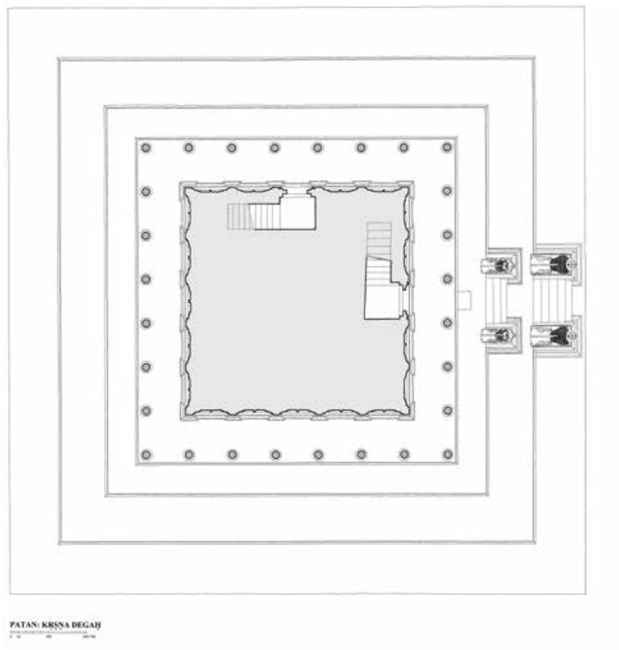
Right
Mahabaudhha Temple, Patan.
(Source: Towers in Stone, by Bijay Basukala, Niels Gutschow, and Kishor Kayastha.Pg 10.)

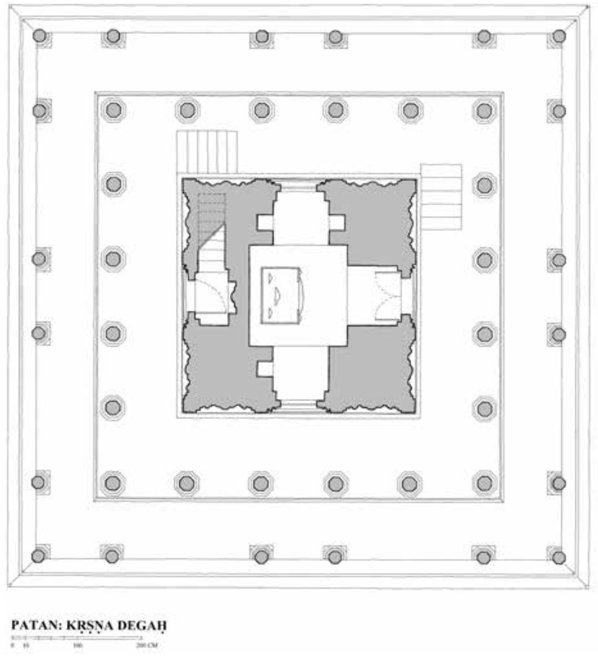
Very few buildings in Nepal are made of stone and up to the 17th century stone was used for votive architecture which were miniature temples and stupas. So both the design and construction of the Krishna Temple was a challenge for the local craftsmen. Walls are made from ashlar masonary and lintels and columns made out of monolithic stone pieces, however, the workmanship does not seem amateur at any point and one can safely assume the rulers bought in experienced craftsmen from India.

The stone pieces were anchored with stone dowels and metal clamps embedded in the stone. They were originally glued together with a local resin called *silay*. The stone construction carried some sort of a numbering system or Mason's marks as the numbers are still visible on the stones. One can also find names etched in the stones which may have been of the stone mason. Another interesting markers are the chisel marks visible on the inner faces of the stones. It is commonly believed that stone was imported from India but petrography results indicate it to be local and the source to be the old lake bed of the Valley.

Top
Alphabets and numbers can be seen in most stone pieces and names of craftmen have also been recorded.

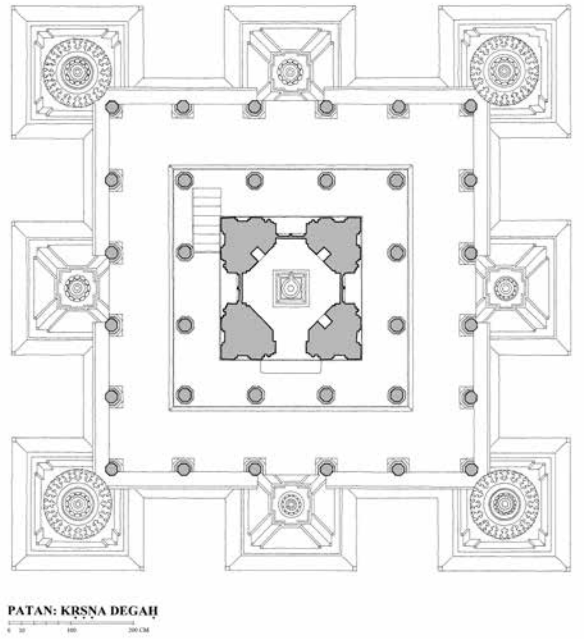
Bottom
The stones of the Krishna temple are fixed stones with metal clamps, stone dowels, and adhesives made from organic materials.

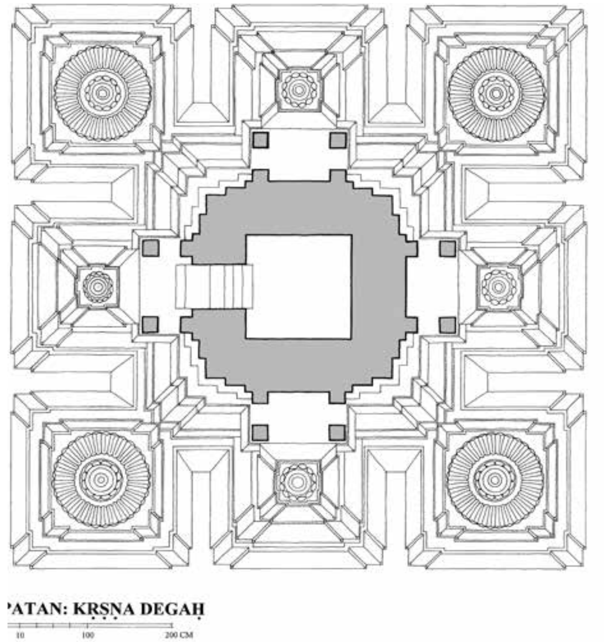




Left
Ground floor plan.

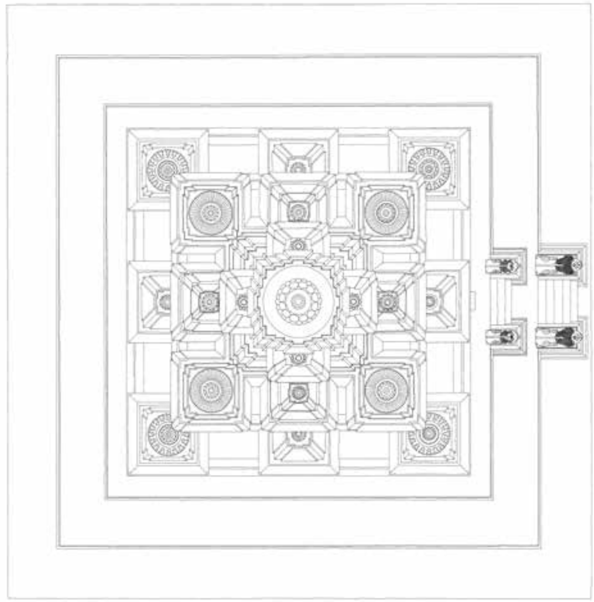
Right
First floor plan.
(Source: Niels Gutschow. Architecture of the Newars. 2011. Pg. 546 & 547.)



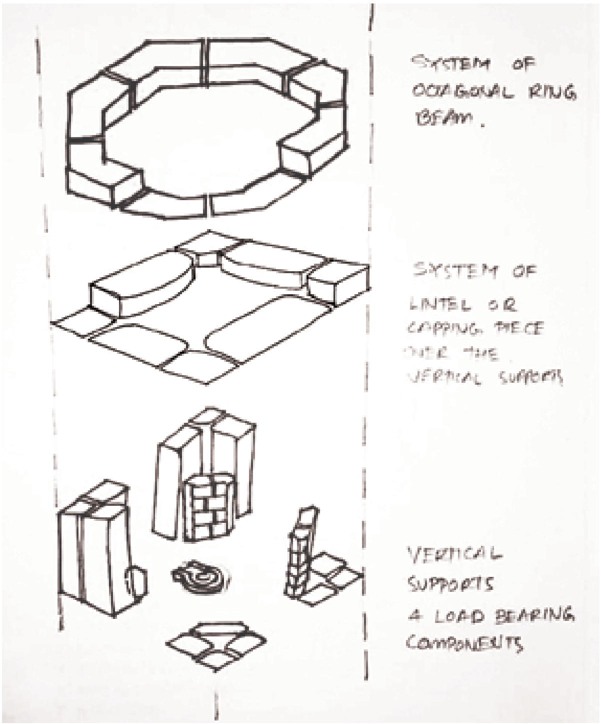


Left
Second floor plan.

Right
Third floor plan.
(Source: Niels Gutschow. Architecture of the Newars. 2011. Pg. 547.)



Roof Floor plan.
(Source: Niels Gutschow. Architecture of the Newars. 2011. Pg. 548.)



Left
Illustrative sketches of the structural system of the Krishna temple by Ramesh Bhole.

Although first floor onwards the temple is built in stone, the plinth and ground floor is probably built of brick and mud infill like the surrounding buildings in the area, and stone is used only as the outermost layer. The high plinth and the ground floor add to the height, thus grandeur, and stability of the temple but the colonnades reduces the visual solidity as the light plays on the changing volumes. More or less symmetrical on all sides, the entry is defined by the majestic lions who guard the entry, also a symbolic signature of the patron, Narasimha, which means a lion. This iconography seems to have been repeated in the pavilions above, where *garuda simbha* stand and guard the *chatris* and *shikara*.

The first floor is entered through two narrow and steep staircases. The idol is seated within a simple, but ornate, *garbha griha*. Whereas the ground floor has a single colonnade, the upper two floor have double colonnades around the central mass. The second floor is entered again through two narrow and steep staircases. This floor is similar, though much less ornate, than the first floor and with a smaller *garbha griha*. The *shikara*, which can be approached only through a temporary ladder, sits on the second floor *garbha griha* structure. The *shikara* seems to be a traditional corbelled construction with a hollowed out interior commonly followed in Hindu temples.

Gutschow in *Towers of Stone* writes that the Krishna Temple “refined the scale and materials of the architecture of Kathmandu Valley, for its impact was greater than any other single structure and its influence can be seen in 21 temples built over the subsequent

Front facade and West-East Section
(Source: Niels Gutschow.Architecture of the Newars. 2011. Pg. 544 & 545.)

120 years. As towers are most vulnerable to seismic shocks, unfortunately three of these temples have only survived with their lowest platforms, while nine have reconstructed towers."

One can safely assume the builders had not only given great attention to the form of the temple but also to its seismic design. Although the temple has been 'shaken up' during the various earthquakes, but no major damage has been done. From secondary research, discussion with the engineers and architects of KVPT, and the theories of our team members, three major design decisions of the builders could be identified.

The gradual decrease in the central mass leading up to the tower, gave it a strong and stable base. This central core, and most importantly the tower, was 'braced' by the reducing colonnades which would have taken some of the impact of the movements during the earthquake. Finally, the tower itself rests on an octagonal ring beam which transfers its load down to the very bottom of the temple core. Any movement of the tower is further counteracted by the four 'sacrificial' corner stones which were probably designed to 'fail', as they did, during an earthquake.

Thus, the scheme of reducing the core, bracing with colonnades, and reducing the impact through stone members proved to be a perfect seismic design for a majestic temple, reinforcing its distinctness and departure from Indian temple designs. The carvings on the temple also indicate the use of Indian stone carvers, well versed in the art of decoration of Hindu temples, who were probably engaged to fulfill a Newari dream.

The whole temple is beautifully ornamented with abstract, floral, and most often with Hindu iconography with the ground floor being the most ornate, reducing in the consecutive floors as it goes up till the *shikara*. But no wall, column, lintel, or beam was left unadorned; only the subject matter and the quantity of ornamentation varied. Gutschow in *Towers in Stone* mentions that, "we are fortunate to have an in situ inscription on the architectural scheme of the temple, its three-storeyed design with 21 pinnacles, and the successive levels of narrative friezes which wrap the structure."

This inscription is found near the entry. He continues to write that from the 15th verse it informs one of the consecration of the temple which in this context is not *devalaya*, or abode to Gods, but *matha* or a monastery.

Left Bottom
The hollow interior of the Shikara of Krishna temple.

Right Bottom
Loose corner stones of the *Garbha Griha*.

Left Top
A miniatue model of the Krishna temple in Sundari Chowk.

Left Bottom
The ornate entry to the first floor.

Middle & Right Top
The Krishna level is more ornate than the upper Shiva level.

Middle & Right Bottom
Floral ornamentation in the plinth and colonnade on the ground floor.






It calls the temple a 'playground for Balagopala'. The narrative friezes on the ground floor have 55 scenes from the Ramayan and those on the first floor have 36 scenes from the Mahabharata. They are duly labeled in Newari. The third level of the temple, dedicated to Kasivisvanatha, is garlanded by 108 *lingas* inscribed on the lintel stones. All but 9 have not been inscribed with a name of Shiva.

Two local flavors which have no Indian counterparts are the curved eaves typical to a tiered temple and the statues of *dikpala* and *garuda simha*. The stone mason here has translated the curved wooden and clay corner tile into stone with a pleasing final effect. The detail is not lost in its miniature too! Every *chatri* is guarded by four *garuda simha* and the *shikara* by four *dikpala*, or guardian kings. A rudimentary beginning of this statuary can be seen in the early temple at Pashupatinath.

The last part of the inscription found near the entry mentions that lands have been set aside for the upkeep of the temple and the officiating priest. The descendants of Visvanath Upadhyaya, the officiating priest, likened to Vyas and Vasistha, nearly four decades later, still attend the deity to this day. We met the young priest, Pratap Dhar, and he was very happy with the restoration work that was being carried out. He carries out all the religious ceremonies daily in the temple, both in the morning and in the evening.

He pointed out to us, the tall pillar in front of the temple with the metal statue of *garuda*, the mythological bird which is the vehicle of Lord Vishnu. He sits, ever ready to transport his Lord, should he want to go anywhere, near at hand. Similarly, the vehicles of all Gods are present with their temples in Nepal. A small depression below the pillar marks the location where the *havan* or ceremonies were carried out before the idols of the Gods were placed in the temple.

The temple is used daily by the local people for worship and draws many tourists everyday who come to visit the Patan Darbar Square. It is not open to non-Hindus. Only Hindus can visit and participate in the worship. The severe earthquakes are a constant threat to the temple. Since 1991 it has been looked after by the Kathmandu Valley Preservation Trust. After the 1993 earthquake, in 2003, Krishna temple, along with the other monuments of the Kathmandu Valley, were placed under the UNESCO list of Word Heritage in Danger.

Conservation of heritage was initiated by the government of Nepal in 1969. The driving force behind this was Carl Pruscha who came to Nepal in 1967 as a United Nations Planning expert. He had an ambitious plan to declare the Darbar Squares of Kathmandu, Bhaktapur, Patan and some other monuments and sites, as monument zones. This effort was reinforced by the Department of Housing and Physical Planning publishing an Inventory of Monuments under the auspices of UNESCO in 1975. Again Pruscha was involved.

In 1977 Eduard Sekler presented a masterplan for the Kathandu Valley. In 1979 the Nepalese government requested UNESCO to send Brown Morton II to assist them in nominating the Kathmandu Valley for the World Heritage list. Based on this document the World Heritage Committee accepted this nomination in 1979 and along with others the Patan Darbar Square became a Word Heritage Site. After the earthquake of 1993, by recommendations of ICOMOS/UNESCO it was placed on the List of World Heritage in Danger.

The Krishna Temple, a World Heritage Monument, belongs to Newars as a unique piece of architecture that influenced many more temples that came after it. One can clearly see that although the temple may have had its origins in the North Indian temples, by infusing it with its own flavor of Hinduism and Buddhist religion, solving the issues of seismic design, and articulating it with local elements and statuary, Krishna Temple stands majestically grounded and an exemplar of seventeenth century Nepal, in a time when Hindus in India had closed shop on erecting monumental temples.


Top
Edges of the *chatris* articulated by upturned corners imitating wood and clay, and guarded by *garuda simha*.

Bottom
Garuda, the vehicle of Lord Vishnu, perched on a pillar in front of the Krishna Temple.

Chapter 2

Condition Assessement for Restoration

Ground Floor

Despite the fact that only the Shiva level was damaged by the earthquake, the whole Krishna Temple was closely inspected for damage although the other levels did not show any distress due to earthquake. The ground floor of the temple is used by the locals and tourists alike for sitting and resting round the clock. Students, couples, and school children including tourists can be seen playing, resting, or sleeping in the corridors. Due to this there is a lot of wear and tear to the stones at this level.

Some stones were damaged due to climate and erosion. The stones of the whole temple has become darkened due to weathering and probably pollution. Small plants and weeds could be seen growing out of the plinth in various places. Some stone joints had opened and needed to be re-pointed. The stones could be cleaned and re-pointed; but other than that, there was not much structural damage that needed immediate attention at the ground floor.

First Floor: Krishna Level

The temple is approached through a high plinth with a grand staircase flanked by two majestic lions. However, after that the entry to the first floor is through a low, narrow, steep staircase. The steps of this staircase are worn out due to wear and tear of over three hundred years of use.

The Krishna level is used everyday, morning and evening, by devotees and the priests. It opens every morning for *aarti* (vesper service) and *bhajans* (singing of devotional songs). The priest worships the deity and the temple is closed again till the evening. The same rituals are repeated after sunset.

The daily use by the locals keeps the temple vibrant and alive and reduces deterioration due to neglect and disuse. But it causes some wear and tear to the building and the carved stones, especially due to the offerings of vermilion (*sindur*) to the deities carved in the temple walls, and lighting of oil lamps during the evening worship.

There are a few other problems that could be addressed at the Krishna level. There are dark grey mortar joints, probably an old repair job with a cementations product. Salt deposits can be seen inside the *chatris* as a result of water seepage. Since this level has a 'living' deity, worshipped daily, no one is allowed to enter the *garbha griha* except for the priest. Thus we could not enter it for inspection.

Probably due to inconvenience during the rains, tin sheds had been erected in between the *chatris* reducing the aesthetic quality of the façade. The other addition to the main structure is the iron pipe railing. However, both of these may have helped in preventing the damage to this level during the earthquake as they tied the whole level into one composite whole.

Second Floor: Shiva Level

The maximum damage seems to be at the Shiva level (Refer drawing indicating affected area). If one looks at the plans, the structure at this level is the most delicate and the heavy roof is supported on a slender colonnade. It is probably due to this reason that the maximum

The ground floor of the Krishna temple is used for resting by locals and tourist alike.

Left Top
The damaged stones on the plinth of Krishna temple.

Bottom
Damage to the carved stones due to regular wear and tear and offerings of vermilion to the deities.

damage was caused to this level. A narrow and very steep staircase, merely one and a half foot wide, takes one to the second floor.

One could see that this floor was not always in use. It was full of old furniture and other discarded items of the temple and worship. The floor was covered with pigeon droppings. The earthquake had damaged the columns, beams, brackets, which were now dislocated and in a precariously unstable condition. Broken stone pieces lay all around the floor.

Due to the lateral movement during the earthquake, the columns had moved out of plumb; old repairs had come out; the columns, brackets, and bases of the columns had been damaged; the window frames and key stones had been dislodged; and some stones, especially at the corners of the *garbha griha* had been severely damaged. However, the inside of the *garbha griha* was surprisingly intact.

As in the lower floor, water seepage marks could be seen inside the domes of the *chatris*. It was difficult to assess the materials of the door and windows of the *garbha griha* due to the black layer on top. The metal sculptures and finials on the *chattris* needed attention. Again as in the lower floor, one could see the grey pointing on the joints which were indicative of an earlier restoration.

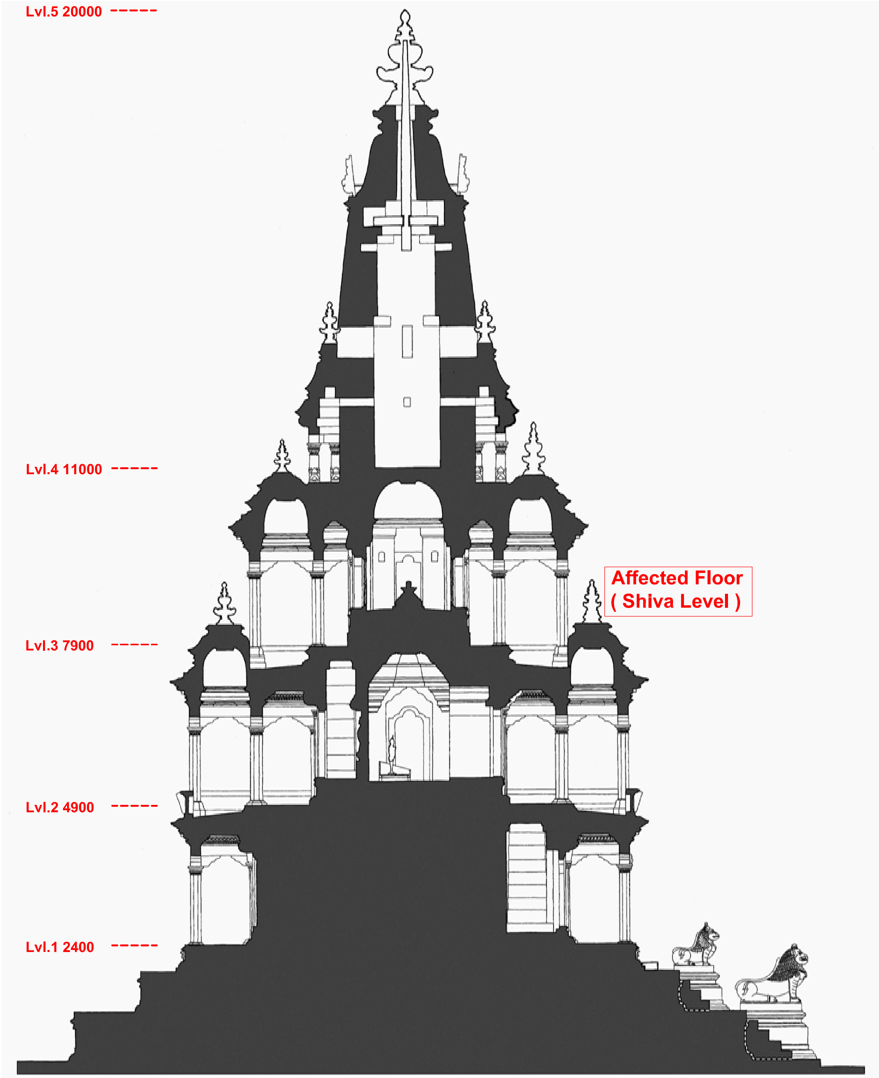
'Shikara' tower

Despite the earthquake and the damage to the lower level, the *shikara* was in a very good condition. Approached through a temporary staircase, one could climb up to the final level which presented a wonderful view of the darbar square . Some stones had deteriorated due to natural conditions. A few small plants could be seen coming out from the joints. Pigeons had made the inside their habitat. Water seepage and open joints were the main problems that were identified in the *shikara*. Metal finials and the sculptures were structurally sound but needed cleaning and some surface restoration.

Top
The *chattris* have been pointed by an un-aesthetic grey mortar during an earlier restoration.

Bottom
White water seepage marks in the *Chattris*.

Right
Section of the Krishna temple.



Section of Krsna Degah, Patan

Section Showing Affected Floor
After Earthquake
Based on a drawing by Niels Gutschow

Left Top, Middle & Bottom
Water seepage, growth of vegetation, eroded stone of the *chatris*, and the internal view of the *shikara*.

Center Top
Damaged and dislocated old pointing repairs.

Center Bottom
Old furniture and dislocated items of the temple stored in the second floor.

Right Top
Corner stones severely damaged.

Right Bottom
The columns were out of plumb due to the earthquake.

Left Top
One of the keystones on the second floor *garbha griha* had fallen off.

Center Top
Other keystones were loose or dislocated. they had to be propped up in place.

Bottom
The inside of the *garbh griha* was surprisingly intact.

Right Top & Bottom
Water seepage marks were visible on the inside of domes.

Restoration History

Extant documents and inspection indicated that the temple has been repaired at some earlier date. As per a report submitted by INTACH (Indian National Trust for Art and Cultural Heritage) Conservation Center, Lucknow, India in April 1989, they were invited by the President, Nepal Heritage Society, Kathmandu to visit and assess the Krishna temple for damage and its restoration. Their report also indicates that an earlier detailed condition survey had been prepared by John Sanday Consultants Private Limited in November 1987.

Both the reports have discussed the deterioration of masonary joints, presence of salt efflorescence due to water ingress, damaged stone work, bio-deterioration of stone, damage due to pigeons, plant growth in the masonary, some minor drainage issues, wear and tear of the staircase and platform, and finally some damaged carvings. None of the issues stated within the report were structural or of any major concern needing intervention.

A general maintenance was probably carried out during this period. The major intervention was sealing the joints. All stone joints were probably re-pointed and stone plastic repairs done. One could easily identify a grey cement-like rigid material all around the temple, especially in the interiors. The outcome is patchy and not very aesthetic. The pointing and plastic repairs have since been dislodged due to the earthquake.

One wonders what was the need for the above intervention in 1989, probably just regular maintenance. Nepal has seen several major earthquakes before 2015. Lying in one of the most seismically active regions of the world, Nepal has a long history of earthquakes. The first documented earthquake event in the country dates back to 7th June 1255, during the reign of King Abhaya Malla. The quake, measuring 7.8 on the Richter scale, took the life of the king and wiped out a third of Kathmandu's then population. Nepal has witnessed at least one major earthquake per century ever since.

The most devastating was on 25th April, 2015 with a magnitude of 7.8 and 8922 deaths. In 1934, the earthquake measured an 8 on the Richter scale and 8519 people died. The other major earthquake was in 1883, also measuring an 8, when 6500 people died. As the Krishna temple was built in 1637, it has seen at least twelve major earthquakes, measuring between 6.5 and 8, but since the above reports do not include any damage due to earthquakes, one assumes that either there was no substantial damage or that these damages were repaired soon after the earthquake.

The evidence in the temple indicates that the temple has been repaired several times before. The first indicator is the level of carving one can see in the capitals and columns. In these capitals the carvings are either not of the same quality as the 'original' carvings, or are sometimes missing altogether. Although an attempt has been made to maintain the same spirit through the colour of stone and the overall patterns, on close inspection one can see the variations.

The second indicator is the use of filler stones in the four corners of the *garbha griha*. As discussed earlier, this temple was probably designed to withstand earthquakes. If one looks at the arrangement of stones carefully, the *garbha griha* is octagonal in plan with a domical roof. The roof rests on a ring beam which in turn rests on lintel beam and transfers the load to the stones below. However, in all the four corners the corner stone is left largely free of the structural system, probably designed

to 'fail' during an earthquake. These corner stones have moved out quite a bit and infill spaces have been filled in by new, thinner pieces of stones over a period of time. This indicates that the temple has been repaired several times in the past.

Interestingly, if one goes behind the museum there is a big yard. It is full of old wooden and stone pieces, both carved and un-carved. The yard, and all it's belongings, are under the Nepal government's archaeological department. Once casually visiting the area, a KVPT engineer pointed out many stone pieces which were similar in pattern and colour to those in the Krishna Temple. One can only guess if these belonged to the same temple or were remnants of the other stone temples that have been destroyed during the earthquakes in the past.

Finally, the third indication of an earlier repair is the variation in pointing. If one looks closely in the interior of the *shikara*, one can see very thin stone joints. The material used here is an adhesive made from organic sources called *silay*, made from pine resin and mixed with vermilion to match colour if needed, as told to us by a local stone mason. He added that this is made from lentil, cotton, and gum. All joints were also reinforced with iron clamps. This was perhaps the oldest method of construction used. When we collected samples for mortar analysis, we found lime, sand, and also stone dust used in the mortars. Restoration mortar in lime and *surkhi* (brick powder) was also present in abundance. Addition of *surkhi* in lime mortars is an eighteenth-nineteenth century phenomenon popularized by the British. Pointing by the 1989 team was grey in colour and some sort of epoxy mixed with cement which is an indication of the current times. Thus, the presence of different mortars indicate that the temple has been restored several times in the past.

Abandoning of the Shiva level for regular worship and encasing the Krishna level with an iron pipe may have been decisions based on its vulnerability due to frequent earthquakes. One can only wonder and speculate at this point. However, one can safely conclude, that the maximum damage due to the 2015 earthquake was at the Shiva level, knocking off the four corner stones again, damaging the capitals and columns again, and rendering the weak joints loose. All these places also indicate earlier repair.

Facing page
Difference in carving style indicates they were done at different times.

Below
Infill stones used during earlier restorations.

Survey of Building Materials

There is a great diversity in Nepal in terms of building materials. Divided into three regions, Tarai, mid hills Pahar, and the higher Himal area, the country presents three different styles of architecture and the use of material which are local to the area. The most common materials in use are brick, wood, and less commonly, stone. Clay was most commonly used to make bricks, as mortars, plasters, and wall finishes. This tradition continues till date and brickwork is still done with clay mortars. A recent survey by the conservation architect indicated that at least five types of clay were known and still in use in the building industry

A grey coloured clay, *Pango*, sourced from Bhaktapur, is used as a mortar after mixing with cow dung and husk. A yellow clay, *Pahelo mato*, from Lele, Lalitpur is used for building a wall above ground. Locally available brown clay, *Kalo mato*, is used for building below ground and

Left & Center
KVPT engineer, Pranam Hora pointed out many carved stone pieces which were similar in pattern and column to those in the Krishna temple.

Right
One sees very thin mortar joints in the interior of the *shikara*.

sometimes in roofs. Pure white clay and red clay are used for plaster and finishing. Variations in colour and their proportions depends on the ethnic groups, thus giving groups of villages their own well defined and distinct appearance.[1]

Because of the abundant availability of good quality clay, bricks became the main blocks for the buildings in Nepal. In the Newar tradition, as the architecture and culture of the Kathmandu Valley is generally referred to, one can see two types of bricks, *daci apa* and *ma apa*. *Daci apa* is the traditional exterior veneer brick. These are the building blocks of the Newar architecture used along with carved wood for the facades. They are well fired and tapered on all the four sides, reducing the joints on the face thereby protecting the mud mortars used for the masonary from rains. *Ma apa* bricks are traditionally low fired bricks used both for interiors, exteriors, and building the cores of the walls.[2] Most building exteriors in Nepal are decorated with ornamental bricks that are specifically made for lintels, cornices, sills etc. and called likewise for example plinth bricks are called *pha apa* and lintel bricks maybe called *mukha phusi* or eyebrow. On observing closely, they take on the patterns and designs from stone and wooden buildings. Due to the large scale restoration work, these bricks have come back into circulation and can be seen used in new buildings also in and around Nepal.

Sestini and Bonapace in their book, *Traditional Materials and Construction Technologies used in the Kathmandu Valley*, give a detailed description of a lime plaster, locally called *bajra* or *vajra*, meaning strong, built of 2 parts brick powder, 1 part lime, and 1 part sand. It has additives such as black treacle for hardening and quick drying; *saldhup*, a resinous oil from Sal tree, jute fibre, *methi*, *mas* or black gram. The same book mentions that Niels Gutschow, a famous architectural historian who has written prolifically on Nepal, describes the same as being made of molasses, 1 part black pulse, jute, 2 parts brick dust, and 1 part lime. Slaked air lime was used for the plaster and whitewashing. Sources say that some lime came from a mine located in Joghi Mara, near Muglin or in Bhainse and Bajura in the Kanali zone.[3] However, currently all building lime for restoration is imported from India.

Nepal is well known for its craftsmen who worked with wood, metal, and stone. Shakya family of Patan is a well known family for its stone work. It is said that Abharay Raj Shakya was a skilled artist working in stone, terracotta, and metal. After marriage, he settled down in Bodhgaya, India. He once found a stone following him, which he picked up and took home. One night he dreamt that the stone was a Buddha telling him to go back to Patan and build a temple in his honor. This is how the Mahabauddha temple was fabled to have been built in the 6th century out of monolithic and carved stone.

Sestini and Bonapace report that Nepal did not have much stone and most was imported from Indian regions of Orissa, Bengal, and Rajasthan since the 17th century for the construction of *shikara* temples. They have also reported some local mines around the hills of Nepal where the stone is close to the surface. The mines are small and easy to excavate but had to be closed down to avoid collapse. These are in the south near Pharping village and Kirtipur city in a place called Macche Narayan Gaon and near Chobar gorge. These are fine packed metamorphic stone which are white (*bhuiya or khairo dhungo*) or black (*kalo dhungo*) in colour. Some marble is also found near the village of Godavari.

The white stone is mostly used for pavements and is more easily quarried than the black stone which is used

1 Traditional Materials and Construction Technologies used in the Kathmandu Valley. Caterina Bonapace & Valerio Sestini.

2 Nepal Patan Palace: Restoration of Sundari Chok (2006-2016). Niels Gutschow & Raju Roka (ed.).

3 Bonapace & Sestini

Middle Top
Clay being prepared for the use as mortar in restoration in Patan.

Right Top
Clay was most commonly used to make bricks, as mortars, plasters, and wall finishes. This tradition continues till date and brickwork is still done with clay mortars.

Left Bottom
Nepal produces many types of bricks, the pattern imitating stone and wooden carvings.

Bottom Middle and Bottom Right
Due to the large scale restoration work, these bricks have come back into circulation and can be seen used in new buildings in and around Nepal

for carvings. The black stone is stronger and more elegant after polishing. Some religious works of importance are made on sites where the stone outcrop is found as in the case of the sleeping Vishnu in Banepa ghats, carved *in situ* by Dharma Raj Shakya, a famous artist of Patan. For Boudhanikhanta Vishnu from the 7th century, the stone probably came from the Chobar gorge. Examples of the use of stone for carving can be found since the 3rd century belonging to the Gupta period as in Changu Narayan and Pashupatinath temples.[4]

From the above literature one can conclude that there was some stone available locally in Nepal and some was imported from India. On the Krishna temple site, we could identify at least three types of stones. A dark bluish gray stone which was used in the corners of the four capitals around the *garbha griha*. It looked very hard and was un-carved. It may have been used to bear the load of the *shikara*. A pinkish gray carved stone was used in the corners of the *garbha griha* and a brownish yellow carved stone for the capitals and other ornamental features.

4 Bonapace & Sestini

Since most of the stones have turned quite dark due to weathering, the above identifications were done from the fractured areas. Samples of these stones were sent for testing to confirm if they conformed to the available information. Samples of these stones were also given to the local stone merchant for survey to find if these were available in the local market and their respective cost. Samples of mortar were also collected from the Krishna temple restoration site for analysis and for the preparation of the restoration mortar. Results of the same are presented leter.

Right Top
Dark bluish grey st=sed in the corners of the four capitals around the *garbha griha*.

Right Middle
Pinkish grey stone used corners of the *garbha griha*.

Bottom Left & Right
Yellow stone is used for the capitals and other ornamental features.

Chapter 3:

Conservation Planning and Management

Conservation Planning

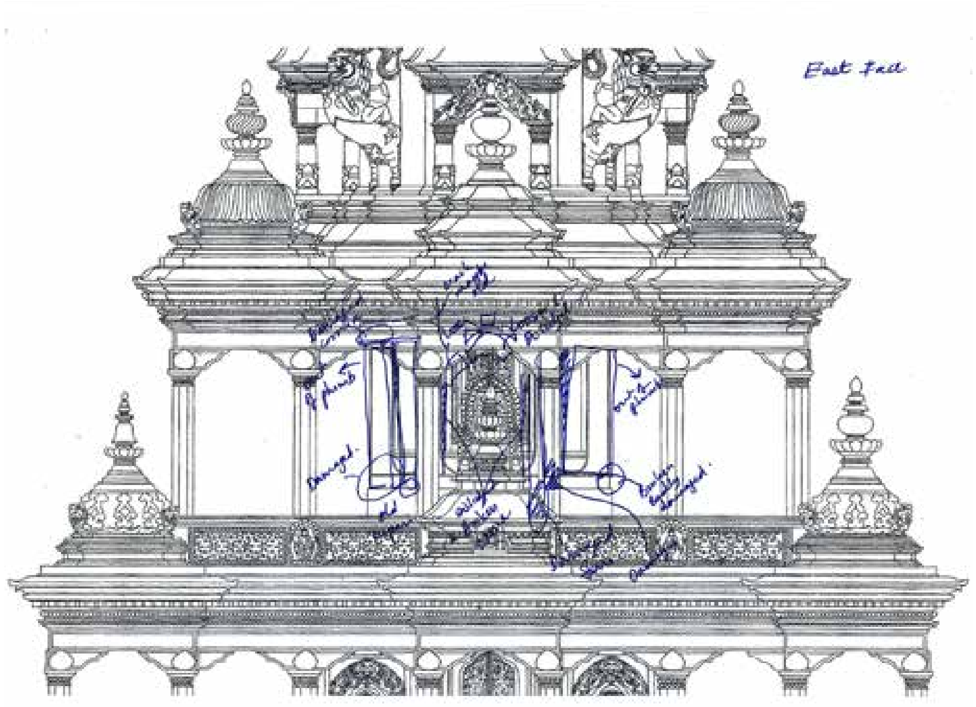
On the invitation of the Kathmandu Valley Preservation Trust (KVPT), the team members of Neeta Shubhrajit Das Associates from Kolkata first visited the Krishna Temple, Patan in October 2015 to assess the problems. The team included Neeta Das, team leader and conservation architect, Ramesh Bhole, associate professor in School of Planning and Architecture, Bhopal, a conservation architect with experience in stone conservation, and Sumanto Roy from MASCON, a contractor with specialization in restoration of heritage structures. It was expected that the team would assess the damage incurred due to the earthquake of April 2015 and submit a brief report with a preliminary estimate.

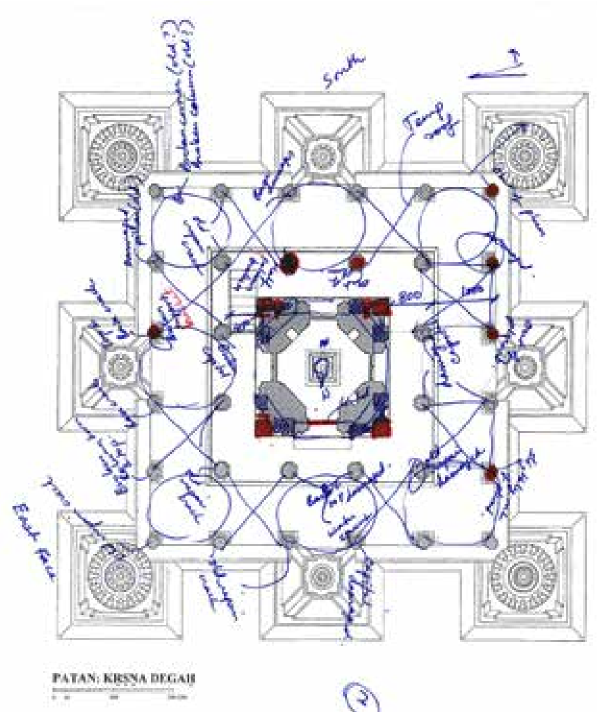
Meeting was held with the directors, engineers, and supervisors of the KVPT. The other projects of KVPT were visited to understand the working systems in Nepal and procurement of building materials by them. The team visited all floors of the Krishna temple. Only the Shiva level was structurally unsound; many dislodged stones had become loose and many had fallen off. Even during the inspection warning signs were put up to prevent visitors, especially tourists, from venturing into the affected floor. The Shiva, or second floor was designated as a hard hat area. The rest of the floors were unaffected. Each and every floor of the temple was inspected and the problems noted. Shiva temple, being the restoration site, was inspected in greater detail. The affected floor was measured for preparation of working drawings. Damaged areas were identified on base drawings made by Niels Gutschow and the KVPT office for future reference. Dangerously and precariously positioned stones and lintels were propped immediately. Stone and mortar samples were collected for testing. Since the colonnade bays are very narrow, strategies for repair were discussed with the architects, engineers, and contractors.

The first scheme was given by MASCON, India. Their estimate and schedule of works included a turn key operation with the contractors taking a restoration team from Kolkata to execute and supervise the work. They would also carry the necessary equipment and restoration materials from Kolkata. Only labour and some common building materials like sand and cement would be sourced locally. Their proposal was finalized and sent for approval and funding. However, this system of out sourcing work to an Indian agency was not approved by the Nepal government. They refused to pay the Indian contractors from the money that was deposited in their account by the German funders for the restoration of the Krishna temple. They agreed to pay the men locally daily for the work done. But this method was not acceptable by MASCON and they refused to execute the project.

A new team and a new system had to be developed for the restoration. At the time it was felt that there was not enough knowledge base to conserve a stone structure in Nepal. So another restoration contractor from Kolkata, CALTECH , was approached to do the job. They visited the site and presented a proposal in which they would supervise the restoration whereas the local men would do the job. Most man power and materials would be sourced locally and only those that were not available in Nepal would be imported. Discussions were held with many stone contractors and masons. Local materials

Opposite page
Scaffolding being erected for the restoration of the Krishna Temple. It was sponsored by the Japanese Government.





Left and Right Top
Presentation drawings prepared by Niels Gutchow were used as base drawings to locate problems. These were later transfered to the working drawings prepared by Neeta Shubhrajit Das Associates.

Bottom Center
Meeting on site with KVPT team of conservation architect, engineers, supervisors, senior consultants and Department of Archaeology representative.

Bottom Right
The Shiva level was designated as a hard hat area due to it's unstable condition.

used for restoration were collected for testing. KVPT presently does not use the services of contractors to do their restoration work but keeps the masons on their pay roll. They believe that the quality of work is much better if the men are not worried about losing their job. Therefore, the proposal given by CALTECH, while involved paying the stone mascons daily and directly, was also not approved by KVPT.

The above exercise took nearly six months and the funders were getting restless as the work had not started. So finally it was decided that the work would be done by the KVPT team as per the specifications of the conservation architect and structural engineer. A team from KVPT comprising of two engineers, one site supervisor, and two stone masons was finalized. It was agreed upon that this team would not change till the completion of the project. The team would interact with the project head, conservation architect, and the engineers, weekly through emails, photographic documentation, and other conferencing soft wares like Trello. All decision taken on site would be in consultation with each other and would conform to the specifications laid down by the consultants.

In the mean time detailed measure drawings were prepared by the conservation architect's office of the second (Shiva) floor where the major restoration was to take place. Based on these, all defects and damages were mapped and interventions planned. Before starting of work, meetings were held in office and site with all members of KVPT and NSDA. Two sets of drawings were made available to KVPT by NSDA. As work continued, these working drawings were updated and provided to the site for execution. Although the KVPT team had been finalized, they were not convergent with stone buildings and their restoration. Therefore, a training program was held for the team by the conservation architect.

Top Left
Pinaki Ghosh from CALTECH on his first site visit.

Top Right
Ramesh Bhole, Stone Specialist; and Sumanto Roy from MASCON, on their first site visit.

Bottom Left
Before the visit of the team from India, the unstable lintels had been propped using wooden members.

Bottom Right
Unstable corner stone propped immediately after the earthquake.

Training Program

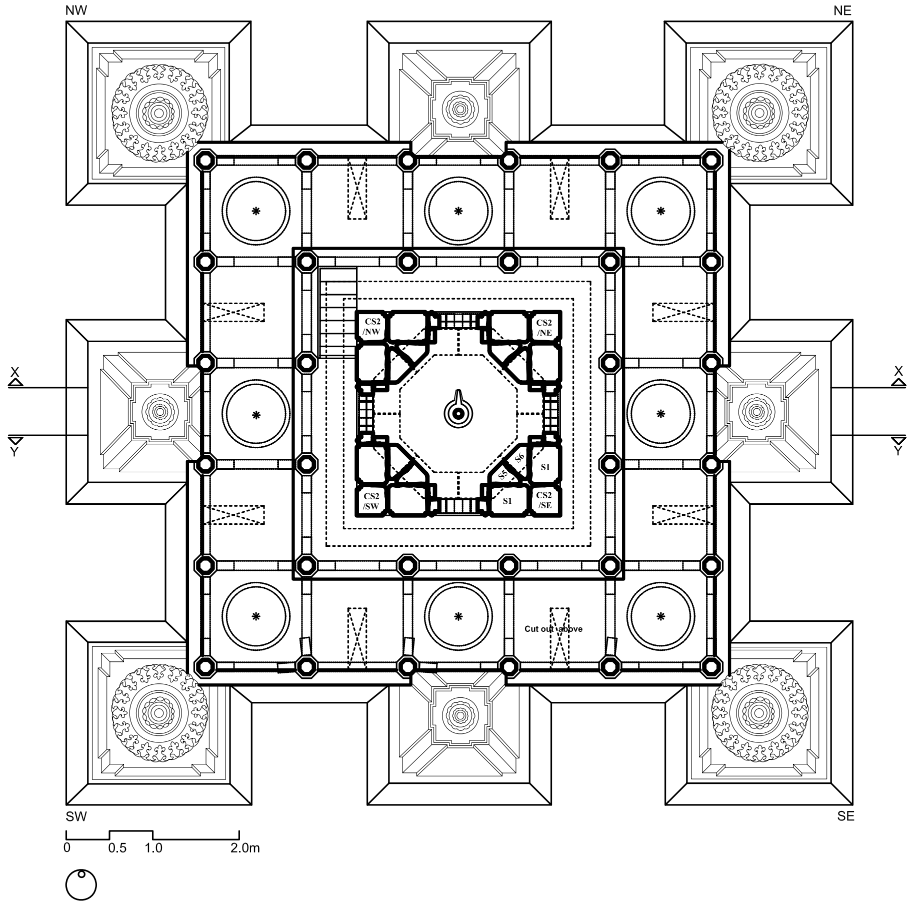
Professor Ramesh Bhole from School of Planning and Architecture, Bhopal, India and Dr. Neeta Das conducted the training program. The two issues that needed understanding were stacking of the broken stones and the construction system of the temple. But the first instruction was to inspect and ensure that the site was secure for working and no loose pieces would fall and damage the workers. Hard hats and other safety precautions had to be taken and any loose stones were to be stabilized with proper jacks and wooden props. The instruction for sorting of stone included:

1 Clear areas on site or procure boxes in which to store the retrieved and labeled stone to be re-used for restoration. Buy good amount of bubble wrap to keep decorative stone after removal.

2 Mark the cardinal directions on the four sides of the site with chalk/ signage clearly mentioning N, S, E, and W. The sign should be clearly visible to all and should

Left Top
Stone sample collected for testing to find a match for restoration.

Left Bottom
Ultra-sound test being conducted by Mariya Milchin from Austria.



Second Floor Plan Showing Stone Sizes

Drawing by Nilufa Rahman and Suchismita Bhattacharya, 2016

Approximate Stone Details

Stone no.	L (cm)	B (cm)	H (cm)
S1.	45	35	116
CS2.	35	35	116
S3a.	12.5	16	71
S3b.	20	16	14
S3c.	20	16	12.5
S3d.	30	16	7.5
S4.	7.5	15	116
S5.	24.5	15	20
S6.	34	15	20
S7.	27	16	17.5
S8.	44	13	5
S9.	117	35	20
S10.	57	35	20
S11.	20	20	20
S12.	7.5	41	90
S13.	45	20	20
S14.	20	20	135
S15.	Capital	Capital	Capital

not damage any historic material. We need to do trials of marking using paint, chalk, pencil and glass marking or coloured pencil and check its life and removal method (oil paint, 2b or 4b pencil, checking red pencil, eraser, paint remover, Fevikwik).

3 Start by sorting stones into 3 types: a/ Those that can be clearly identified and numbered; b/ Those that may be later used; and c/ Those that are too small for repair.

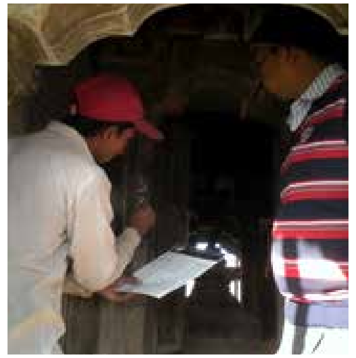
4 Stones 3a are to be clearly numbered as per numbers given on the drawing along with the direction and stored carefully. Care has to be taken that the numbering is on the back, clearly visible, and not liable to be wiped off while handling. It should also not permanently damage the stone and is visible after completion. Since the number of pieces will be small, the entire process can be done on the relevant floors.

5 Stones 3c are to be kept aside for making stone dust for use in mortars and fillings. Masking tape, salo tape and acrylic polymer and silicon repellant for surface protection of 3a stones to be used.

ww6 Jacks, chain pulleys, etc. should be used to shift or lower any large pieces of stone carefully.

7 All pieces/ boxes to be stored in a clean, well lighted, and dry place for future use.

Thedimensional components of the temple is built up of monolithic pieces of stones, monolithic columns, monolithic lintels etc. Over a period of time these have been replaced and repaired making the structural system weak and vulnerable to seismic forces. To have a clear understanding of the stone locations and for better common understanding, drawings were prepared with each stone of the second floor having a unique number . These drawings were checked on site to match with the existing conditions. The number was then duplicated with chalk on the temple walls marking each stone. This made the restoration work very easy as everyone could follow, whether sitting far off in an office or on site, which stone was being replaced or repaired. This system of identification was continued till the end of the restoration.



Bottom Left
Ramesh Bhole explaining the system of numbering to the stone mason, Surya Bahadur.

Bottom Center
Carved stones were numbered by permanent markers on the back.

Top Right
Stone masons collecting the stone pieces from the floor

Bottom Right
Stone mason being trained to number stones with white chalk.

Left Top
Small pieces of broken stone collected for preparation of stone dust.

Left Bottom
Broken carved pieces were stored in buckets for reuse.

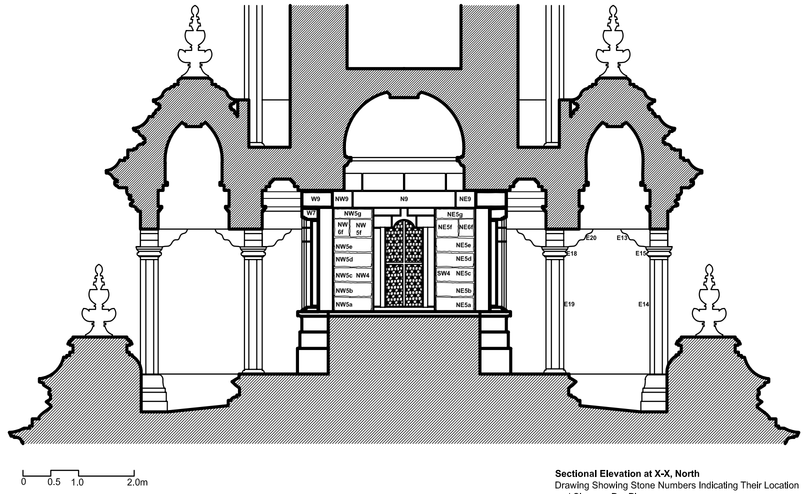
Center Top
Boxes used to collect and store the broken stone pieces.

Center Bottom
Stone mason being helped by trainer to match broken piece.

Right Top
Broken stones numbered for safe storage.

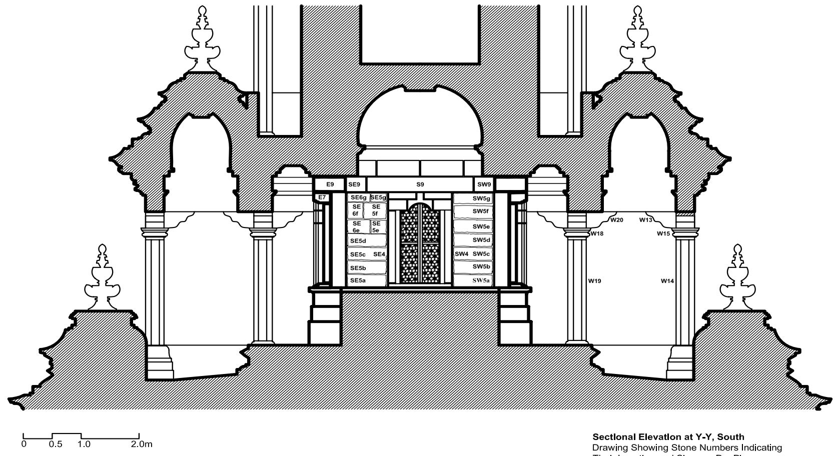
Right Bottom
Stone mason matching the broken stones with on-site conditions.

The KVPT engineers and stone mason were trained to number the stones. Later, they numbered every inividual stone which had a matching number on the working drawings. this system was continued till the end.



Sectional Elevation at X-X, North
Drawing Showing Stone Numbers Indicating Their Location and Sizes as Per Plan

Drawing by Nilufa Rahman and Suchismita Bhattacharya, 2016



Sectional Elevation at Y-Y, South
Drawing Showing Stone Numbers Indicating Their Location and Sizes as Per Plan

Drawing by Nilufa Rahman and Suchismita Bhattacharya, 2016

Philosophy of repair

When the work started it was decided that attempt would be made to make the structure strong and stable as it was greatly damaged because of the earthquake. Minimum intervention would be done to the structure and almost no ornamental repair would be attempted. Recommendations and specifications were initially made keeping this philosophy in mind. However, as the project started this thinking was modified.

Once the Nepal government refused to allow the Indian team to work on the temple, non-intrusive restoration methods were not possible with the Nepali team of workers. They were unaware of the scientific methods of stone consolidation. However, they were good stone carvers, who could reproduce new of the old damaged stones and repair the fractured and broken stone members. Keeping this in mind it was decided to replace, rather than repair, the severely damaged stone pieces. Stones with minor damage were repaired.

The KVPT Director of Nepal, Rohit Ranjitkar, also felt this to be a better philosophy for restoration since it helped in the revival of the traditional crafts. These crafts, and craftsmen, would help restore other historic stone structures. Eventually the restoration was executed by an all Nepali team of engineers, stone masons, and supervisors under the able guidance of Rohit Ranitkar using local and traditional systems. The foreign consultants simply offered their advice from time to time and oversaw the progress of work. This method of work was also approved by the Nepali government and went in the favour of the local craftsmen. So all in all it was a win-win situation for everybody.

Although it was initially decided that only structural work would be done and this would be restricted to the second floor or the Shiva level, this was later changed. A team from the University of Applied Arts, Vienna visits Nepal every year with a group of interns. They offer voluntary services to KVPT and assist in the restoration. In 2017-18 they worked on the Krishna temple in

Left
Corner stone crushed into small pieces.

Right
The Shiva level being cleaned of debris from earthquake and pigeon dropping and garbage.

which they restored the *shikara* and *chatris* by replacing damaged stones and re-pointing it as and where needed. They also restored the metal ornamentation that decorated the temple. Later some other decorative restoration, like cleaning the metal doors of the *garbha griha*, and minor restoration works in other floors was done by the KVPT team.

Preliminary works

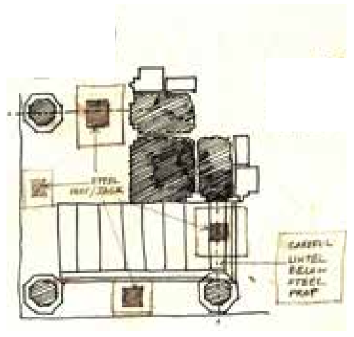
When the team first visited the site, it was in an appalling condition. It housed dozens of pigeons and the floor was covered with several inches of bird droppings. The Shiva temple was not used on a daily basis like the lower Krishna level so had become a store room for un-used items. It had wooden items, a harmonium, old doors and windows, and discarded temple trinklets. Added to the regular garbage was the debris of the stones that had been broken and were flung away from their sources. The place needed to be cleaned before proceeding any further.

Four men were engaged for cleaning the place. They swept away the bird droppings and removed all the un-used temple items. Boxes and buckets were made available to sort and collect the broken stone pieces. They were duly numbered as per architect's drawings and stored. These boxes and buckets were then kept in the *garbha griha* for future use. The smaller stone pieces were collected and later crushed by hand for use as fine aggregate for making lime mortar. Once the place was cleaned, safety became the next most important issue.

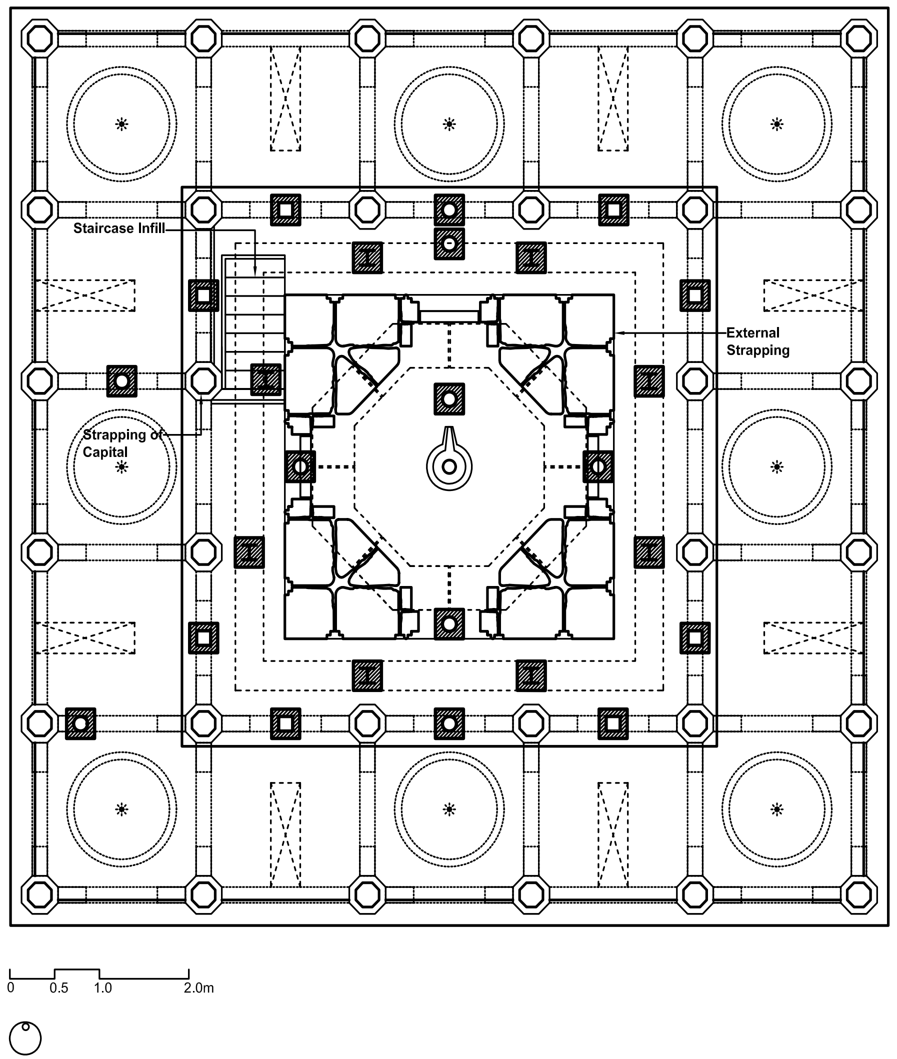
Signs were posted to dissuade visitors from entering the restoration site. The Shiva or second floor was designated as a hard hat area and no one, consultants and workers alike, was allowed to enter the place without a proper safety hat. As per the site, sketches were prepared indicating columns and beams that needed to be propped up immediately. Both wooden and iron props were to be used as and where required. These sketches were later formalized as working drawings. Erecting of the scaffolding was the next task.

Left
Small timber base plates have been added at the foot of the scaffolding to avoid direct contact and to protect the stone against abrasion of the metal.
(*Photo: KVPT October 18, 2016.*)

Right
Care was taken to prevent damage to the stone members by using protective material.



Sketches made on site by conservation architect, Neeta Das, indicating location of props, which were later transferred on the working drawings.



Second Floor Plan Shoring and Prop Details

Drawing by Suchismita Bhattacharya, 2016

150X75 I-Section with base plates

100X100 Channel column with base plates

100X75 Wooden prop with base plates

The design of the scaffolding was a complicated task. It had several roles to play. It had to assist in the transport of men and heavy stone pieces up and down the three floors. It had to partially support some of the load when the structural members were being changed. The design of the scaffolding had to be such that it would not hinder the working and movement of large stone pieces. Several schemes were designed and rejected. The final design was a joint venture of KVPT, the consulting engineers, and the conservation architect.

Initially the scaffolding was erected only up to the Shiva (second floor) level. However, when the team from Vienna came, this scaffolding was extended till the

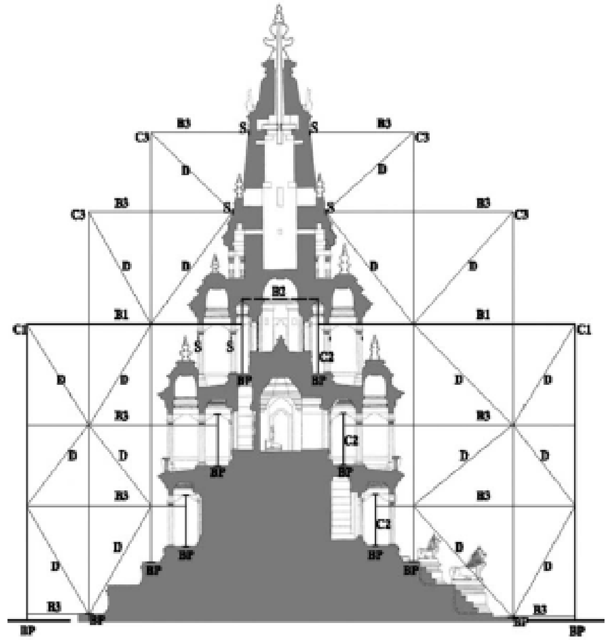
Left Top
Steel box beams were designed so as to fit right into the carved soffits.

Left Bottom
Steel props with base plates supporting the Shiva level roofing

Center Top
Staircase in the north west corner of the Shiva level.

Center Bottom
The staircase had to be filled with sand to provide a base for the steel props.

Right Top
Two C- sections were welded together to form a square section which were used as a vertical prop to support the stone beams.
(*Photo: KVPT. Nov. 25, 2016.*)



Left Top
The pulley system prepared for transferring new stone pieces is being tried.
(*Photo: KVPT. May 09, 2017*)

Center Top
Initial design of scaffolding by the architect's office which was later revised.

Right Top
Scaffolding was extended up to *shikara*.

Right Bottom
Cross bracing is being added to the scaffolding for transferring the new stones to the Shiva temple level.
(*Photo: KVPT. Mar. 20, 2017.*)

topmost point of the temple pinnacle. The stone lintels of the temple were initially supported by steel box beams, which in turn were propped up by steel columns. It was made sure that these stone columns transferred the load down to the base of the temple. In the north west corner due to the location of the staircase, leading down to the Krishna level, it was difficult to erect the steel column. After much deliberation, it was decided to fill up the staircase with sand and use it as a flat base for the supports.

In the meantime, stone and mortar testing was done. A matching stone was found in the Kathmandu Valley and ordered for. The engineering team of KVPT made several mortar samples based on the recommendations of NSDA and finally decided on one after having it tested from the Tribhuvan University of Nepal. Large pieces of stone were transported to the site in trucks. These were indigenously lowered and moved to the site with tackles and on circular pipes where they were finally cut into the required sizes and carved for use.

Material Analysis and Testing

Three samples of each type of stones were collected from various places for testing. Samples of these stones were also given to the local stone merchant for survey if these were available in the market and their respective cost. Samples of mortar were also collected from the Krishna temple restoration site. Three types of mortars were found. The first type was an adhesive made from organic sources called *silay*. The mason informed us that it was made from lentil, cotton, and gum. Although this was abundantly used in the *shikara* of the temple, it could not be tested for use in restoration. Inorganic adhesives were instead used.

The second type of mortar was reddish brown in colour, made up of air hydrated or non-hydraulic lime, sand, and *surkhi* or brick powder. It was probably a repair mortar. The third type of mortar was pinkish white in colour. After testing it was found to be made up of

Left
Large pieces of stone were transported to the site in trucks. These were indigenously lowered and moved to the site with tackles and on circular pipes where they were finally cut into the required sizes and carved for use.
(*Photos: KVPT. Dec 29, 2016.*)

Right
Newly carved base stone for the northeast corner is being carried and transferred to the Siva temple level for installation.
(*Photos: KVPT. July 13, 2017.*)

Left Top
Stone sample that was finally selected.

Left Bottom
Bagged sample for testing.

Right
Workshop of Chandra Shyam Dangol.

hydraulic lime, sand, and clay. This may have been the original mortar because non-hydraulic lime is not used for stone construction, which needs quick setting properties, in cold climates such as Nepal where it is difficult to cure due to the long setting time. Acid dissolution test forms the basis of these results. The results have been verified through X-Ray Diffraction test and Chemical Analysis of the mortar. Details of these reports have been attached along with.

Before starting the work, a detailed market survey was done across Nepal to identify the materials needed for restoration. Some materials like building lime and clay was collected from the ongoing restoration works in Patan. Samples of sand, *surkhi* (brick powder) and stone were collected for testing. We met two stone suppliers with their samples and rates. Mr. Tirthram Kashichwa gave us grey samples whereas we needed yellow samples, which he provided to us later. He informed us that the soft gray and yellow stone was sourced from a stone quarry in Butwal, about three hundred kilometers from Patan, north of Palpa district. It has been used in the Bhaktapur Darbar Square. The black stone is sourced from a stone quarry in Pharpian, Kathmandu. However, since the road connecting it to the main land is very narrow, only small pieces of five to ten feet long and one to two feet wide could be transported. He also informed us that he had stone masons who could help us in the work on site. We visited the sites of Mr. Chandra Shyam Dangol, a stone carver and saw his techniques and materials. He was doing very good work but with gray black stone.

The sand samples collected and tested were found to be gray in colour and medium coarse river sand. Since no building codes of Nepal could be found, Indian Standard Codes were used for the interpretation of the results. Among the interesting finds of the survey was the practice of breaking stone into stone dust by small hammers that we saw in one of the sites of Mr. Chandra Shyam Dangol. We later used similar stone dust to prepare our mortar. No building lime sources or suppliers could be found in Nepal. The ongoing projects were using a semi-hydraulic air lime from Reliance Industries , Jamnagar, in India.

Among the other things not easily available in Nepal were the synthetic adhesives, pins, and restoration mortars. We approached two companies, Remmers and CTS, to provide their specifications for the various items. After careful deliberation, we finally selected an epoxy resin Araldite AY 103 and CTS EPO 121 for fixing of stone. Since these could not be found another Indian product with similar properties, Bondtite Super Strength from Resinova was used. Pins suggested were 316 threaded SS or CTS Fiber glass threaded bars where stainless steel pins were finally used.

The only other item left for restoration was the development of the restoration mortar. The restoration mortar had to be of the same colour as the original; its property had to match with the original; and it had to be easy to prepare with ingredients locally available. Local sand being gray and *surkhi* being red could not be used

due to their colour. Instead stone dust from the rubble collected on site was selected as the fine aggregate. Since stone construction needed a hydraulic lime, as also indicated in the mortar analysis, it had to be imported from India. Remmers NHL 3.5 was selected for use.

Five proportions based on the original mortar after mortar analysis were suggested. These were made from hydraulic lime but with clay, stone dust, and/or imported sand of matching colour in various proportions. These were prepared by the site engineering team and tested in the Department of Civil Engineering's Central Material Testing Laboratory of the Tribhuvan University in Nepal. Based on the results, one of the five samples, with a good colour match and consistent results, was used for restorations. The selected sample is yellow in colour and made with hydraulic lime, yellow sand, and yellow stone dust.

Three samples each of three historic stones used in the Krishna temple, and three samples each of the new stone suggested by the local stone supplier were taken for testing for properties match. A petrography test was done for all the samples. All the historic stones used in the temple were sedimentary rocks with a higher percentage of clay. Two of them were fine grained arenaceous shale whereas one was a fine grained sand stone, with 47% of sand thus termed arginllaceous (Wacke). It was yellowish brown in colour.

Two new stone samples were gray in colour and one was grayish brown. Unlike the earlier stones which were clayey all these stone were calcareous in nature. Two were sedimentary sand stones (Wacke) and one was metamorphic shale. Due to matching properties of colour and composition we selected the grayish brown sandstone. Both the new and old sample were argillaceous Wacke and were in tones of brown. Further

Right Top
Building Lime from Reliance Industries, Jamnagar, India being used by KVPT.

Center Top
Stone dust being manually made from small pieces of stone.

Center Bottom
Mortar samples being prepared by the site engineering team.

Right Middle
Adhesive used for fixing stone during restoration.

Right Bottom
Local crafts man working with gray stone.

Mortar Analysis

Date/ Age of Mortar	17-18 Century CE. / 378yrs
Function	Mortar

Physical Examination

Size	65.4mm x 50.3mm x 38.1mm
Sample received	Broken Pieces
Hardness	Firm
Friability (dust)	Moderate
Binder type	Mortar
Binder Strength	Strong
Carbonated	Yes
Munsell Colour	2.5 YR 4/4 Reddish Brown

Details can be seen in the petrography and EDX reports.

Weight of Sample

Before Drying	Error
After Drying	58.59gms

Acid Dissolution & Filtration (24 hrs in acid)

10% HCl solution	Strong reaction
Lasting	Few minutes (25 minutes)

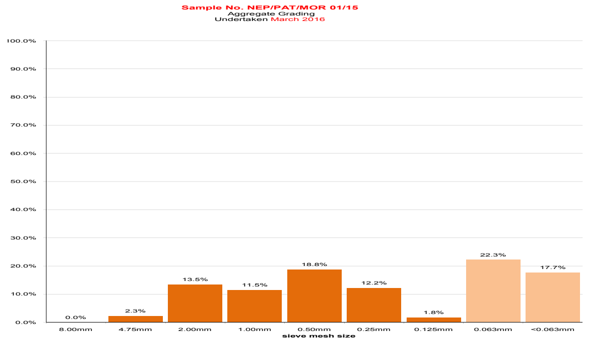
Aggregate Filtering and Drying

Wt. of dried sub-sample after filtration 34.91gms

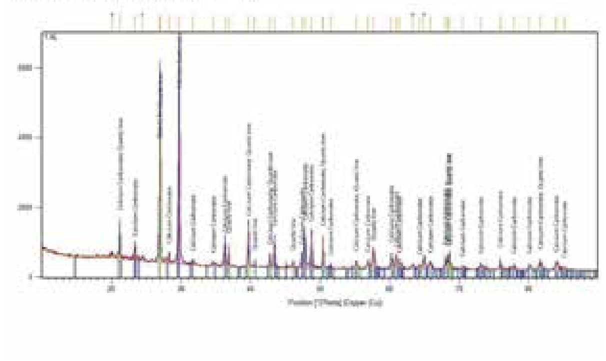
Conclusion

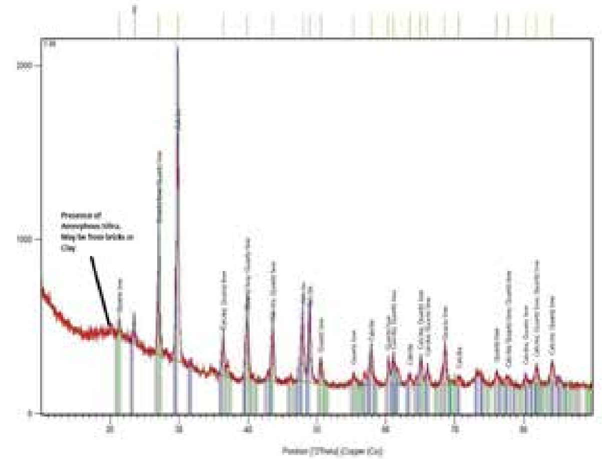
The lime mortar has binder 35.63 gm (air lime 23.68 gm, clay 12.03 gm) and sand 30.43 gm (1:1). After acid dissolution the aggregate has 60% of sand and 40% of *surkhi* clay.

The tests were carried out in the Lime Center, Kolkata and confirmed by *Dr. S. Thirumalini, Vellore Instt. of Technology.*



XRD Results (Before Acid Dissolution)





Aggregate Grading: Sample No: NEP/PAT/MOR-01/15

Photograph (Under Microscope)	Sieve Number	Aggregate wt. retained (g)	Remarks (under microscope)
	4mm	0.69	Angular brick bats. Colour:5 YR 6/6 reddish yellow
	2mm	4.06	Angular brick bats. Presence of charcoal and quartzite. Colour: 5 YR 6/6 Reddish yellow.
	1mm	3.47	Angular brick bats. Presence of charcoal and quartzite which is increasing. Colour: 5 YR 6/6 Reddish yellow.
	500 micron	5.66	Angular small brick bats. Presence of charcoal and quartz which is increasing. Colour: 7.5 YR 5/6 Strong brown.
	250 micron	3.68	Angular tiny pieces of brick bats. Presence of charcoal which is increasing. Colour: 7.5 YR 5/6 Strong brown.
	125 micron	0.53	It may be *Surkhi* or brick dust. Colour: 5 YR 5/6 Yellowish red.
	63 micron	6.71	Fine dust may be *Surkhi* Colour: 7.5 YR 5/6 Strong brown.
	Less than 63 micron	5.33	Very fine dust may be *Surkhi.* Colour: 7.5 YR 6/6 Reddish yellow.

Mortar Analysis by Acid Dissolution of the reddish brown mortar, probably a restoration mortar.

Mortar Analysis

Date/ Age of Mortar	17-18 Century CE. / 378yrs
Function	Mortar

Physical Examination

Size	52.5mm x 42.9mm x 2mm.
Sample received	Intact
Hardness	Firm
Friability (dust)	Eminent
Binder type	Mortar
Binder Strength	Strong
Carbonated	Yes
Munsell Colour	7.5 YR 8/2 Pinkish White

Weight of Sample

Before Drying	Error
After Drying	59.22gms

Acid Dissolution & Filtration (24 hrs in acid)

10% HCl solution	Strong reaction
Lasting	Very long (24hrs.)

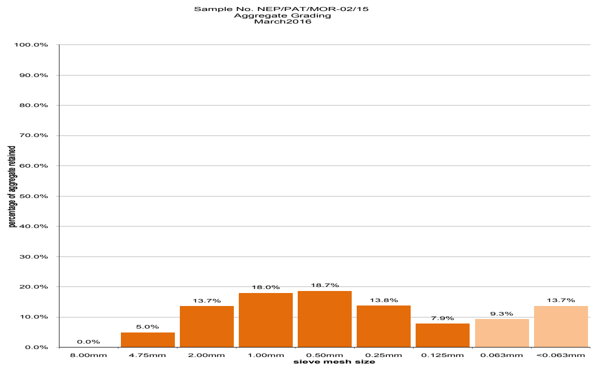
Aggregate Filtering and Drying

Wt. of dried sub-sample after filtration	49.64gms

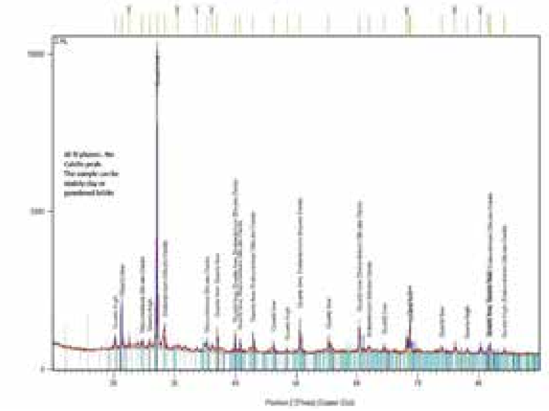
Conclusion

The lime mortar has binder 20.91 gm (Hydraulic lime 9.58 gm, clay 11.33 gm) and sand 38.31 gm (1:2). After acid dissolution the aggregate has 69% of sand and 23% of clay.

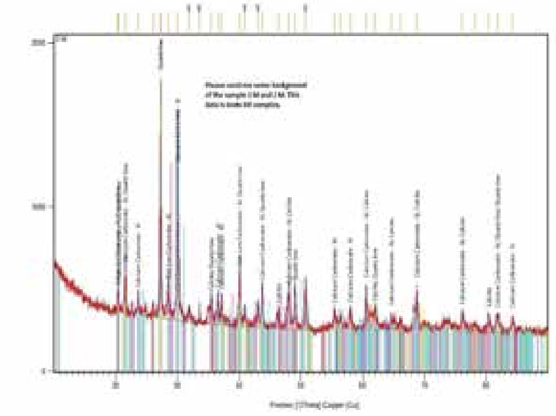
The tests were carried out in the Lime Center, Kolkata and confirmed by *Dr. S. Thirumalini, Vellore Instt. of Technology.*



XRD Results (Before acid dissolution)



XRD Results (After acid dissolution)



Aggregate Grading: Sample No: NEP/PAT/MOR-02/15

Photograph (Under Microscope)	Sieve Number	Aggregate wt. retained (g)	Remarks (under microscope)
	4mm	2.37	Angular brick bats and angular charcoal. Colour: 5YR 7/6 Reddish yellow, 6/1 bluish gray.
	2mm	6.54	Angular brick bats. Presence of charcoal and lime patinated *kankar*. Colour: 5YR Reddish yellow, 6/1 bluish gray.
	1mm	8.60	Angular brick bats. Presence of lime patinated *kankar* and charcoal which is increasing Colour: 5 YR 6/6 Reddish yellow.
	500 micron	8.92	Angular brick bats. Presence of charcoal and quartz which is increasing Colour: 7.5 YR 7/4 Pink, 6/3 Light brown.
	250 micron	6.61	Rounded small brick bats. Presence of charcoal and quartz which is increasing Colour: 7.5 YR 6/4 Light brown.
	125 micron	3.76	Brick particle, charcoal particle and quartz which is increasing. Colour: 7.5 YR 7/3 Pink.
	63 micron	4.45	Fine dust may be *Surkhi* or silt. Colour: 7.5 YR 6/4 Light brown.
	Less than 63 micron	6.55	Very fine dust may be clay. Colour: 7.5 YR 6/6 Reddish yellow

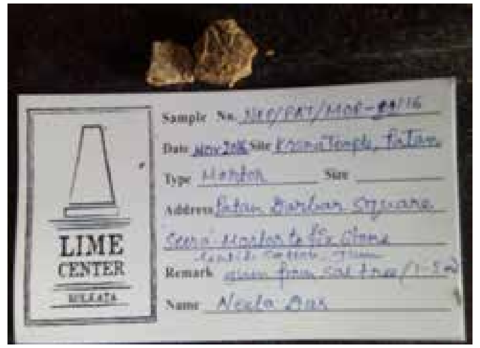
Mortar Analysis by Acid Dissolution test of pinkish white mortar.

Building Mortar

Function Adhesive

About Specimen:

The selected sample (No. NEP/PAT/MOR-22/16) is collected from Krishna temple, Patan Area, Nepal by KVPT. This is a type of adhesive made from organic sources. It is called "*Silay*" and made from lentil, cotton and gum. This was abundantly found in the *shikara* of the temple.



Stone Analysis

Date/ Age of Mortar	New stone
Function	New stone for restoration

Physical Examination

Sample received	Condition Good
Weight received	267.24 gm
Munsell colour	2.5 Y, 5/2 Grayish Brown
Reaction to acid	Strong (10% HCl)
% Water Absorption	Slightly absorbed

The selected sample (No. NEP/PAT/STN–23/16) is collected from Krishna Temple, Patan Area, Nepal. The stone is fine grained, Calcareous Argillaceous sandstone (Fine grained sedimentary stone with sand sized particles) with clay 18.01%, calcium cement 16.95%, quartz 53.32% and other minerals 11.72% in volume.

[NPS_23_16new.raw] NPS_23_16New — Peak ID Report

SCAN: 10.0/90.0/0.05/0.75(sec), Cu(40kV,30mA), I(cps)=4396, 02/22/17 04:20p

PEAK: 9-pts/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

NOTE: Intensity = CPS, 2T(0)=0.0(deg), Wavelength to Compute d-Spacing = 1.54059Å (Cu/K-alpha1)

#	2-Theta	d(Å)	Height	Height%	Phase ID	d(Å)	I%	(hkl)	2-Theta	Delta
1	20.789	4.2693	967	22.1	Quartz	4.2550	16.0	(100)	20.860	0.071
2	23.037	3.8575	49	1.1	Calcite	3.8600	12.0	(012)	23.022	-0.015
3	23.987	3.7068	47	1.1	Artinite	3.6900	50.0	(4̄01)	24.098	0.111
4	26.608	3.3475	4373	100.0	Quartz	3.3435	100.0	(101)	26.640	0.032
5	29.396	3.0359	294	6.7	Calcite	3.0350	100.0	(104)	29.405	0.009
6	36.510	2.4591	309	7.1	Muscovite-3T	2.4570	8.0	(114)	36.542	0.032
7	39.417	2.2842	302	6.9	Calcite	2.2850	18.0	(113)	39.402	-0.015
8	40.254	2.2385	127	2.9	Quartz	2.2361	4.0	(111)	40.300	0.045
9	42.384	2.1309	438	10.0	Diaspore	2.1310	52.0	(121)	42.381	-0.003
10	43.188	2.0931	49	1.1	Calcite	2.0950	18.0	(202)	43.146	-0.042
11	45.758	1.9813	151	3.5	Quartz	1.9799	4.0	(201)	45.793	0.034
12	47.105	1.9277	82	1.9	Calcite	1.9270	5.0	(024)	47.124	0.019
13	47.514	1.9121	69	1.6	Calcite	1.9130	17.0	(018)	47.490	-0.024
14	48.516	1.8749	81	1.9	Calcite	1.8750	17.0	(116)	48.513	-0.003
15	50.115	1.8188	503	11.5	Clinochlore-1...	1.8180	5.0	(224)	50.137	0.023
16	54.854	1.6723	150	3.4	Quartz	1.6717	4.0	(202)	54.875	0.020
17	55.284	1.6603	50	1.1	Clinochlore-1...	1.6600	5.0	(2̄43)	55.295	0.011
18	59.930	1.5422	376	8.6	Quartz	1.5415	9.0	(211)	59.960	0.029
19	64.036	1.4529	73	1.7	Quartz	1.4529	2.0	(113)	64.035	0.000
20	65.782	1.4185	44	1.0	Quartz	1.4184	1.0	(300)	65.786	0.003
21	67.715	1.3826	269	6.1	Quartz	1.3821	6.0	(212)	67.744	0.028
22	68.151	1.3748	270	6.2	Quartz	1.3750	7.0	(203)	68.144	-0.007
23	73.456	1.2881	45	1.0	Clinochlore-1...	1.2880	5.0	(262)	73.461	0.006
24	75.645	1.2561	84	1.9	Diaspore	1.2560	4.0	(321)	75.656	0.011
25	79.886	1.1998	92	2.1	Quartz	1.1998	2.0	(213)	79.884	-0.002
26	81.154	1.1842	47	1.1	Quartz	1.1840	2.0	(114)	81.173	0.018
27	81.494	1.1801	84	1.9	Quartz	1.1802	2.0	(310)	81.491	-0.003
28	83.806	1.1534	121	2.8	Quartz	1.1530	1.0	(311)	83.840	0.034

Line Shifts of Individual Phases:

00-046-1045> Quartz - SiO_2 <2T(0) = 0.0, d/d(0) = 1.0>

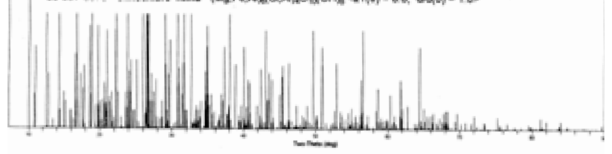
00-005-0355> Diaspore - AlO(OH) <2T(0) = 0.0, d/d(0) = 1.0>

00-005-0586> Calcite - $CaCO_3$ <2T(0) = 0.0, d/d(0) = 1.0>

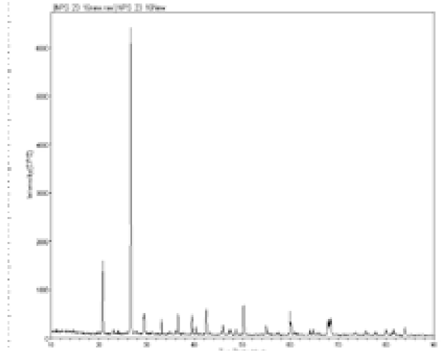
00-006-0484> Artinite - $Mg_2CO_3(OH)_2{\cdot}3H_2O$ <2T(0) = 0.0, d/d(0) = 1.0>

00-007-0042> Muscovite-3T - $(K,Na)(Al,Mg,Fe)_2(Si_{3.1}Al_{0.9})O_{10}(OH)_2$ <2T(0) = 0.0, d/d(0) = 1.0>

00-007-0078> Clinochlore-1MIIb - $(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$ <2T(0) = 0.0, d/d(0) = 1.0>



The tests were carried out in the Lime Center, Kolkata and confirmed by *Dr. S. Sinha, University of Calcutta (Geology Dept.).*



Stone Analysis

Date/ Age of Mortar	1637
Function	Masonary stone (Carved)

Physical Examination

Size (largest piece)	65mm x 25mm x 20mm
Sample received	Condition Good
Condition	Deteriorating
Weight received	278.42 gm
Mussel colour	10 YR , 6/8 Brownish Yellow
Reaction to acid	Weak (10% HCl)
Formations	Nil
% Water Absorption	Not tested

The selected sample (No. NEP/PAT/STN-06/15) is collected from Krishna Temple, Patan, Area Nepal by Kathmandu Valley Preservation Trust (K.V.P.T), Nepal. The stone is carved and is fine grained, Arenaceous Shale (Fine grained sedimentary stone) with green clay 20%, colourless clay 33%, and quartz 47% in volume.

[NPS_7_15old.raw] NPS_7_15old — Peak ID Report

SCAN: 10.0/90.0/0.05/0.75(sec), Cu(40kV,30mA), I(cps)=2067, 02/22/17 03:58p

PEAK: 11-pts/Parabolic Filter, Threshold=3.0, Cutoff=0.1%, BG=3/1.0, Peak-Top=Summit

NOTE: Intensity = CPS, 2T(0)=0.0(deg), Wavelength to Compute d-Spacing = 1.54059Å (Cu/K-alpha1)

#	2-Theta	d(Å)	Height	Height%	Phase ID	d(Å)	I%	(hkl)	2-Theta	Delta
1	20.960	4.2348	447	21.7	Quartz ✓	4.2349	16.0	(100)	20.960	-0.001
2	22.109	4.0174	50	2.4	Anorthite	4.0223	22.0	(2̄02)	22.081	-0.028
3	22.457	3.9559	84	4.1	Unnamed	3.9500	8.0	(060)	22.491	0.034
4	24.097	3.6902	29	1.4	Artinite	3.6900	50.0	(4̄01)	24.098	0.001
5	25.555	3.4829	95	4.6	Antigorite-6...	3.4800	10.0	(120)	25.577	0.022
6	26.746	3.3305	2061	100.0	Muscovite-3T	3.3310	100.0	(009)	26.741	-0.004
7	28.037	3.1799	189	9.2	Artinite	3.1800	10.0	(401)	28.037	-0.001
8	29.502	3.0253	186	9.0	Anorthite	3.0283	9.0	(211)	29.472	-0.031
9	31.321	2.8536	45	2.2	Gismondine	2.8610	2.0	(032)	31.238	-0.084
10	35.049	2.5581	67	3.3	Diaspore	2.5580	30.0	(130)	35.051	0.002
11	36.641	2.4506	132	6.4	Quartz	2.4504	9.0	(110)	36.644	0.003
12	39.582	2.2750	134	6.5	Gismondine	2.2745	6.0	(1̄42)	39.592	0.009
13	40.365	2.2327	66	3.2	Anorthite	2.2312	2.0	(15̄2)	40.392	0.027
14	42.549	2.1230	166	8.0	Quartz	2.1229	6.0	(200)	42.550	0.001
15	45.900	1.9755	64	3.1	Quartz	1.9758	4.0	(201)	45.893	-0.007
16	48.172	1.8875	38	1.9	Antigorite-8.0M	1.8860	1.0	(033)	48.212	0.040
17	50.247	1.8143	228	11.1	Quartz	1.8146	13.0	(112)	50.239	-0.009
18	50.629	1.8015	42	2.0	Quartz	1.7984	1.0	(003)	50.722	0.093
19	51.130	1.7850	55	2.7	Thermonatrite	1.7870	8.0	(600)	51.069	-0.061
20	54.998	1.6683	79	3.8	Gismondine	1.6682	8.0	(352)	55.001	0.002
21	55.359	1.6582	52	2.5	Clinochlore-1...	1.6600	5.0	(2̄43)	55.295	-0.064
22	60.088	1.5386	145	7.1	Anorthite	1.5387	1.0	(4̄28)	60.083	-0.004
23	67.849	1.3802	100	4.9	Quartz	1.3803	6.0	(212)	67.844	-0.006
24	68.252	1.3730	169	8.2	Brucite	1.3730	16.0	(103)	68.254	0.002
25	73.543	1.2868	46	2.2	Quartz	1.2864	2.0	(104)	73.567	0.025
26	75.754	1.2546	54	2.6	Gismondine	1.2546	1.0	(2̄74)	75.756	0.002
27	79.966	1.1988	47	2.3	Quartz	1.1986	2.0	(213)	79.984	0.018
28	81.294	1.1825	43	2.1	Quartz	1.1828	2.0	(114)	81.273	-0.021
29	81.567	1.1793	48	2.3	Calcite	1.1795	3.0	(2,1,10)	81.547	-0.020
30	83.927	1.1520	42	2.0	Quartz	1.1519	1.0	(311)	83.940	0.013

Line Shifts of Individual Phases:

00-046-1045> Quartz - SiO_2 <2T(0) = 0.1, d/d(0) = 1.0>

00-020-0452> Gismondine - $CaAl_2Si_2O_8{\cdot}4H_2O$ <2T(0) = 0.1, d/d(0) = 1.0>

00-041-1486> Anorthite - $CaAl_2Si_2O_8$ <2T(0) = 0.1, d/d(0) = 1.0>

00-002-0095> Antigorite-6.86M - $Mg_{3-x}[Si_2O_5](OH)_{4-2x}$ <2T(0) = 0.0, d/d(0) = 1.0>

00-005-0355> Diaspore - AlO(OH) <2T(0) = 0.0, d/d(0) = 1.0>

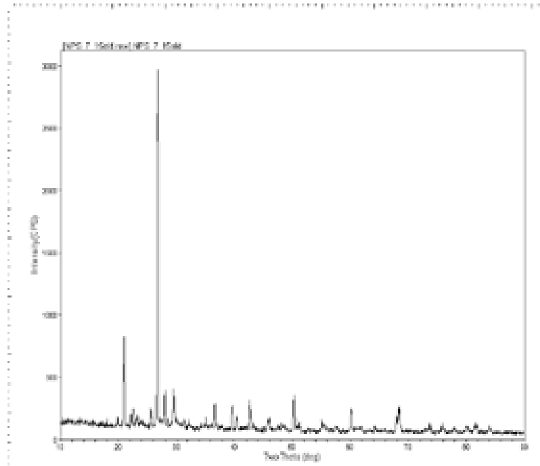
00-005-0586> Calcite - $CaCO_3$ <2T(0) = 0.0, d/d(0) = 1.0>

00-006-0484> Artinite - $Mg_2CO_3(OH)_2{\cdot}3H_2O$ <2T(0) = 0.0, d/d(0) = 1.0>

00-007-0042> Muscovite-3T - $(K,Na)(Al,Mg,Fe)_2(Si_{3.1}Al_{0.9})O_{10}(OH)_2$ <2T(0) = 0.0, d/d(0) = 1.0>

00-007-0078> Clinochlore-1MIIb - $(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$ <2T(0) = 0.0, d/d(0) = 1.0>

00-007-0239> Brucite - $Mg(OH)_2$ <2T(0) = 0.0, d/d(0) = 1.0>



Petrography details of the historic carved stone.

The tests were carried out in the Lime Center, Kolkata and confirmed by *Dr. S. Sinha, University of Calcutta (Geology Dept.).*

Interpretation and Recommendation for stone samples to be used for the Restoration of the Krsna Temple, Patan, Nepal

SN	Sample Number	Function	Dated	Munsell	Colour		Physical Analysis				Minerals				Classification		Common Name	Remark
					Hue	*Value*	*Grain*	*Porosity (%)*	*Den-sity*	*Reaction to HCL*	*Sand (%)*	*Clay (%)*	*Calcite (%)*	*Other (%)*	*Chemical*	*Geological*		
1	NEP/PAT/STN- 23/16	Restoration	New	Brown (Grayish)	2.5 Y	5/2	Fine	4.8	2.3	Strong	53.32	18.01	16.95	11.72	Calcareous Argillaceous	Sedimentary	Sand stone (Wacke)	Matched
2	NEP/PAT/STN-21/16	Restoration	New	Light Gray	2.5 YR	7/2	Very Fine	3	2.3	Strong	40.07	15.25	15.25	29.43	Calcareous Argillaceous	Sedimentary	Sand stone (Wacke)	
3	NEP/PAT/STN-19/16	Restoration	New	Dark Bluish Gray	Gley 2	4/1	Fine	1.1	2.2	Strong	3.53	31.02	33	32.45	Calcareous	Metamorphic	Shale	
4	NEP/PAT/STN-07/15	Masonary (Carved)	A.D 1637	Brown (Yellowish)	10 YR	6/8	Fine	5- 4.7	2.59	Weak	47	53	-	-	Argillaceous	Sedimentary	Fined grained sand stone (Wacke)	Matched
5	NEP/PAT/STN-06/15	Masonary (Carved)	A.D 1637	Pinkish Gray	10 YR	7/2	Fine	5- 7.49	2.18	Weak	40	60	-	-	Arenaceous	Sedimentary	Shale	
6	NEP/PAT/STN-05/15	Masonary (Un-carved)	A.D 1637	Dark Bluish Gray	Gley 2	4/1	Fine	5- 1.7	2.56	Weak	30	70	-	-	Arenaceous	Sedimentary	Shale	

Reference: **Arenaceous –** Sandy **Argillaceous –** Clayey (15%-75%) **Calcareous –** Chalky ($CaCO_3$)

Shale Fined grained, sedimentary rock, made up of clay (over 75%), quartz & calcite. **Sandstone:** Sedimentary rock, sand sized materials, made of quartz & feldspar.

Average porosity of Shale: Not greater than 10% (Range)

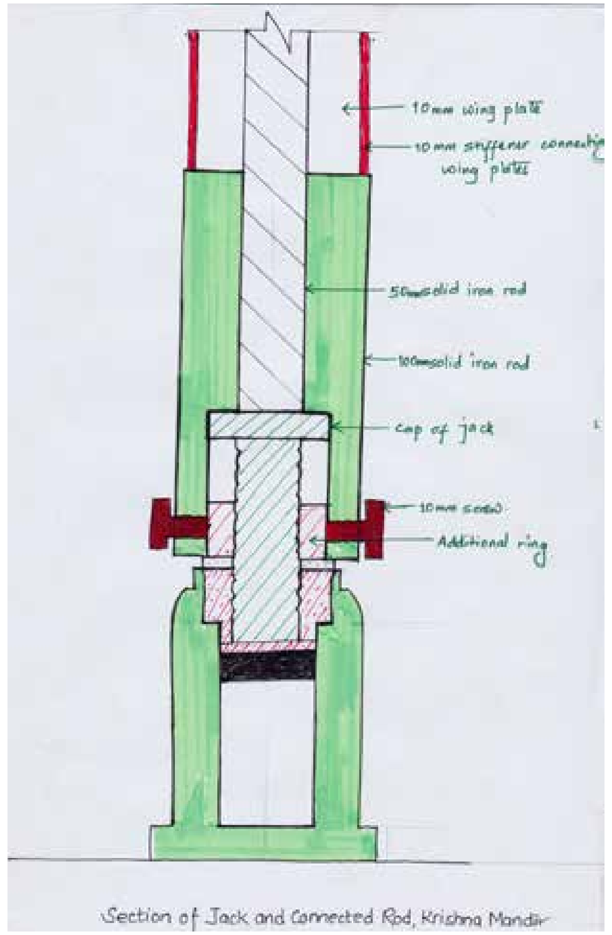
Average porosity of Sandstone: Not greater than 10% (Range)

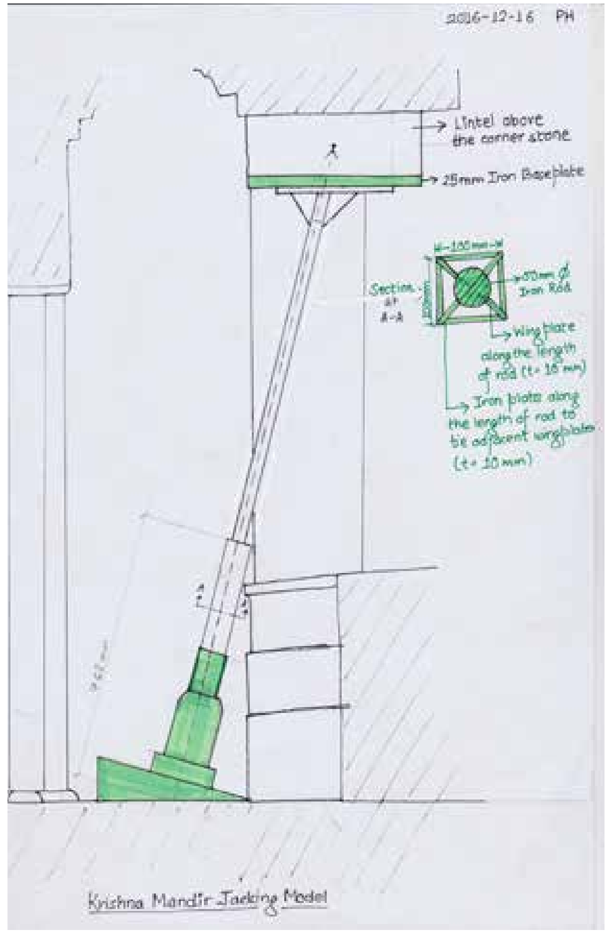
The specific gravity or density of most of the stone lies between 2.3 to 2.5 (Range)

Types of Sandstone: a) Arenite- Sedimentary clastic rock with sand and contain less than 15% clay (matrix)

b) Wacke- A sandstone of which mud matrix in which the grains are embedded amount to between 15%-75% of the mass.

Indicator used to match the historic and new stone samples.





Left Top
Hydraulic jack with 50 ton capacity.
(Photo: KVPT Dec. 14, 2016.)

Center Top
Engineer Pranam is inspecting the jacking system that is being modified at the workshop.
(*Photo: KVPT. Dec. 23, 2016.*)

Center and Right Bottom
Drawings for modification of jack prepared by KVPT engineer Pranam Hora based on the discussion between KVPT staff and conservation architect Neeta Das.
(*Photo: KVPT. Dec. 14, 2016.*)

Left Top
Grinding of stone pieces into stone dust to be used as mortar.
(Photo: KVPT. Mar. 15, 2017.)

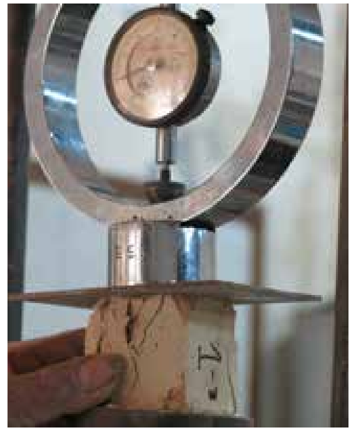
Left Center
Claudio Coralli (consultant engineer) testing the quantity of binder (lime) required for stone mortar mix. Test is being performed to decide the ratio of stone dust and sand for preparing stone mortar.
(Photo: KVPT. Feb 16, 2017.)

Left Bottom
Pooja Amatya, Pranam Hora and Evan Speer preparing mortar mixture for carrying out mortar tests.
(Photo: KVPT. Mar. 23, 2017.)

Right Top and Center
Six mortar testing samples were prepared with different make up and proportion of the binder in order to obtain the right color to best match the stones and also to test the compressive strength. The samples were kept for 28 days as curing/compressive period.
(Photo. KVPT. Mar 23, 2017.)

Right Bottom
The six different mortar test blocks that were created with the NHL lime under observation at KVPT office.
(Photo. KVPT. Mar. 27, 2017.)

Left and Center Top
Six different mortar test blocks that were created with the NHL lime are being cut into cubes for testing at the Central Material Testing Lab of Pulchowk Campus, Department of Civil Engineering.
(Photo. KVPT. Apr 25 & 26, 2017.)



Center Bottom and Right Bottom
NHL mortar samples being tested for compressive strengths at the Central Material Testing Lab of Pulchowk Campus.
(Photo. KVPT. Apr 27, 2017.)

Left and Right Top
Damaged pieces of cornice above corner column.
(Photo: KVPT. Jan. 02, 2017.)

Left Center
Damaged original corner stone at Shiva level.
(Photo: KVPT. Jan 22, 2017.)

Left Bottom
Damaged corner threshold stone of innermost sanctum *(garbha griha)* at Shiva level.
(Photo: KVPT. Dec. 26, 2016.)

Right
Staicase was blocked, that leads to the second floor (Shiva Temple level) filled with bricks and mud for shoring. Corner stone was missing in this North South corner, replaced with lime *surkhi*.
(Photo: KVPT. Nov. 28, 2016.)

Left Top
Damaged threshold stone at southeast corner of innermost sanctum *(garbha griha)*. Vertical shoring, using "I" section columns with iron base plates have been added in the four corners of the second floor (Shiva Temple level) to provide additional support for the upper structure and to allow for in situ repair of the out of plumb columns in the four corners and replace the base of corner columns.
(Photo: KVPT. Nov. 23, 2016.)

Right Top
Sample stainless steel strapping is being tried out on the damaged transitional piece *(cokulan)* between the capital and the column to hold the broken pieces together on the east side.
(Photo: KVPT. Dec 23, 2016.)

Left Bottom
5 cm iron angle adjustable strapping around innermost sanctum *(garbha griha)* at Shiva Temple level is installed.
(Photo: KVPT. Dec 06, 2016.)

Right Bottom
Fabric strap is being installed around the stones below the lintel level to hold the stone pieces together before removing the corner piece at the southwest corner of Shiva Temple level.
(Photo: KVPT. Feb. 16, 2017.)

Left Top
Cleaning of the carved stones was carried out at Krishna level (*Mahavharat epic*) and at ground floor (*Ramayana epic*) with soft brush and 5 % acetone solution. *(Photo: KVPT. Mar. 20, 2017.)*

Right Top
All the stones have been cleaned to check for visible cracks. The staircase that leads to the second floor (Shiva temple level) was filled with bricks and yellow mud for shoring in future. *(Photo: KVPT. Nov. 25, 2016)*

Bottom
Ash Bahadur Ranjitkar preparing new stone to replace the damaged ones in the Shiva temple level. Carving details is being added to a new piece of stone by stone mason Surya Bahadur. *(Photo: KVPT. Apr. 06, 2017)*

Left Top
Stone mason Asha Bahadur Ranjitkar preparing a new stone to replace the corner damaged piece on the Shiva Temple level. *(Photo: KVPT. Jan 24, 2017.)*

Card board stencil was made based on damaged original piece in full size to mark on stone before carving on stone to get right proportion. *(Photo: KVPT. Mar. 17, 2017.)*

Left and Right Bottom
Carving details being added to the new piece of stone to replace damaged corner stone in the Shiva temple level by stone mason Surya Bahadur Ranjitkar. *(Photo: KVPT. Mar 02 & Mar. 09, 2017.)*

Chapter 4:

Structural Commentary

Evan Speer

Means and Methods

Although, in the context of the Patan Darbar Square, the extent of structural repairs proposed for Krishna Mandir were relatively small, the logistics and means and methods for executing these repairs presented larger challenges to the project. The methodology required to move such large stones with precision in a weakened stone structure is of utmost importance to reduce further risk to the structure during construction. As Krishna Mandir is a unique structure on the Square, and the site team did not have as much experience in this architectural style as with typical Newar brick masonry and timber construction, this methodology was extremely important.

Stone Hoist

The repairs to the structure required lifting large replacement stones, weighing up to 700 kg, to the Shiva level, approximately 5 m above the square level up. The site team's original scaffolding layout and hoist procedure needed to be altered to ensure safe transfer of stones. Scaffolding was altered to establish a single open hoist bay on the south facade with regular cross-bracing to stabilize the bay, an 8" steel wide flange hoist beam, and additional steel tube scaffolding members to strengthen the area around the hoist beam. Due to the height limitations of the chain pulley hoists, the bay would need to be two-staged, following the following hoist procedure:

- The stone is moved to the uppermost plinth level.
- The chain pulley on the hoist beam, situated two bays up on the scaffold, hoists the stone to the highest level possible.
- Wooden planking inserted to support stone
- Chain pully and hoist beam transferred to top of scaffolding.
- Stone hoisted to Shiva level, wooden planks inserted for placement of stone and transfer to building.

Shoring and Scaffold Detailing

Original scaffold designs were not followed by the team on site, and the inclusion of a horizontal member inbound of the outer colonnade at the Shiva level to secure the scaffold to the building was a dangerous detailing mistake. If the scaffolding moved significantly or fell, this member would put horizontal forces into the columns and put them in danger of collapse. It was recommended to move this member outbound of the structure. Good practice in scaffold design is to limit engagement of the actual structure as much as possible. Also, the site team introduced a frame of 6" steel wideflange deadman shores supporting a steel beam at the keystone of the ambulatory vault around the Shiva level core. Due to difficulty of installation and the cut sizes of the members, this frame did not bear any weight before inspection in November 2016. After on-site discussion of the load paths, additional shoring was added via 8" steel wide flange posts inserted in-line with the freestanding columns of the ambulatory.

This construction misstep proved useful, however, because the steel frame became instrumental in the development of the procedure to efficiently remove the corner stones. The steel beam atop the deadman shores was used as a track to attach the chain pulleys needed for corner stone removal. With the teamwork of a metalsmith, a bracket was created with (2) 4" steel

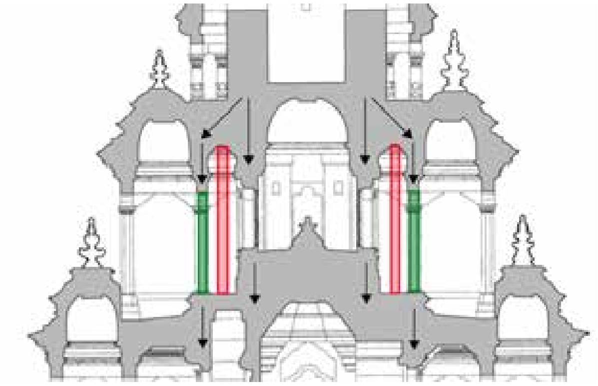
Facing Page
Newly carved base stone for the northeast corner is being carried and transferred to the Siva temple level for installation.
(Photo: KVPT, July 13, 2017.)

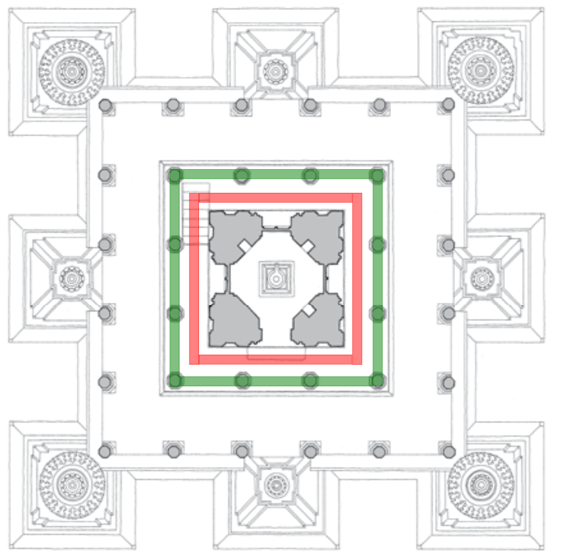
The preservation of Krishna Mandir involved a large multidisciplinary team of Nepali and international artisans and preservation professionals. In addition to the standard team, additional site support was retained from a series of visiting structural engineering volunteers to aid in site supervision and design efforts. The team included:

Dr. Rohit Ranjitkar, *Project Architect*
Dr. Neeta Das, *Preservation Architect Consultant*

Pooja Amatya, *Engineer*
Pranam Hora, *Engineer*
Surya Bahadur Ranjitkar, *Stonecarver and mason*
Evan Speer, *Preservation and Structural Engineering Consultant*
Claudio Corallo, Tim Bowden, and Laura Batty, *Visiting Structural Engineering Consultants*

channel sections to hang the chain pulleys off the lower flange of the beam. Without these beams in place and this site improvization advancement, the removal of the stones may not have been as successful. The column removal procedure is discussed in more detail later in the report.



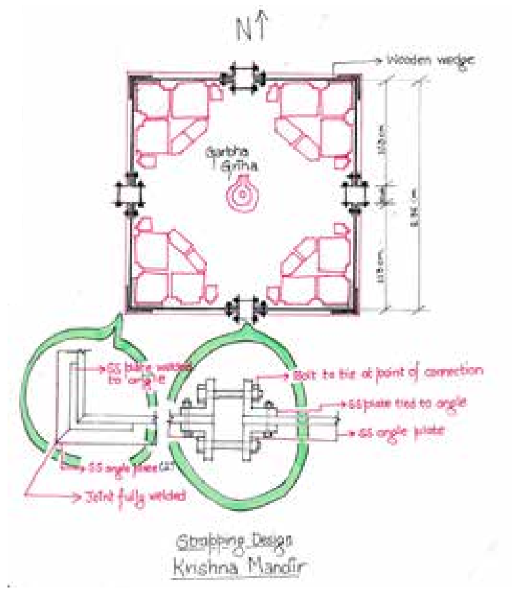


Left Top & Bottom:
Section and plan showing the Shiva level core with the location of the initial shoring shown in red. Shoring in the ambulatory was restricted to areas in green in line with columns to not disturb original load paths (shown in black).
(Sketch by E. Speer, April 21, 2017)

Far right:
Initial fit test and installation of the chain pulley bracket onto the existing steel frame in the Shiva level ambulatory. The chain pulley bracket was made on site with steel channel sections.
(Photos by P. Amatya, November 29, 2016)

Steel Angle Strapping at Core

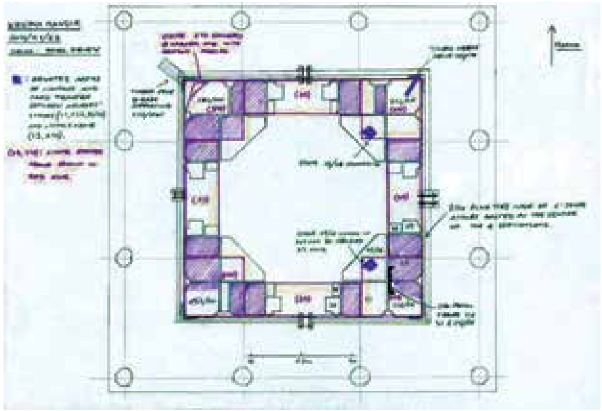
The sensitive and weakened condition of the dislodged corner stones presented concerns of further displacement or dislodgement during construction works on the Shiva level. Therefore, two levels of steel ring ties, each consisting of (4) corner pieces of 2"x2" steel angles, full pen welded in the corners, were introduced to provide confinement around the core. This strapping was originally designed to restrict the weight of the approx. 700 kg corner stones from any further outward displacement during construction, due to vibration of site works or any small tremors that may occur when the structure is in a weakened state. This ring was installed in corner pieces, bolted together and tightened to be snug to the structure, with wooden shims to protect the stones. One band was fabricated in stainless steel to remain after construction works. This will aid in reducing displacement and dislodgement in an earthquake.

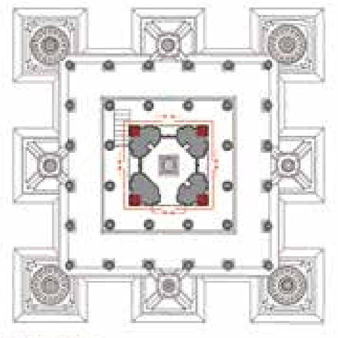


Shiva Level Core Corner Stone Replacement

The most ambitious of the reinforcement procedures was the removal and reinstallation of the corner stones of the Shiva level's core. The project team was able to take the limitations of the Nepali context and develop an inventive procedure to remove massive corner stones at the Shiva level core without changing primary load paths and replace the stones in a fashion that limited damages to the stones and ultimately provided an improved condition.

It must be noted, however, that various strengthening measures proposed, such as proposed steel dowels at the top of the corner stones locations, were not installed. These reinforcing measures would further secure the structure, and it is concerning that these were not installed. But given the circumstances, with the introduced strengthening measures, replumbing of columns, introduction of proper Natural Hydraulic Lime (NHL) mortars, and rebuilt base stones,





Left:
Plan showing the Shiva level core with the tension ring strapping around the core to restrict further displacement of the corner stones.
(Drawing by P. Hora, November 29, 2016.)

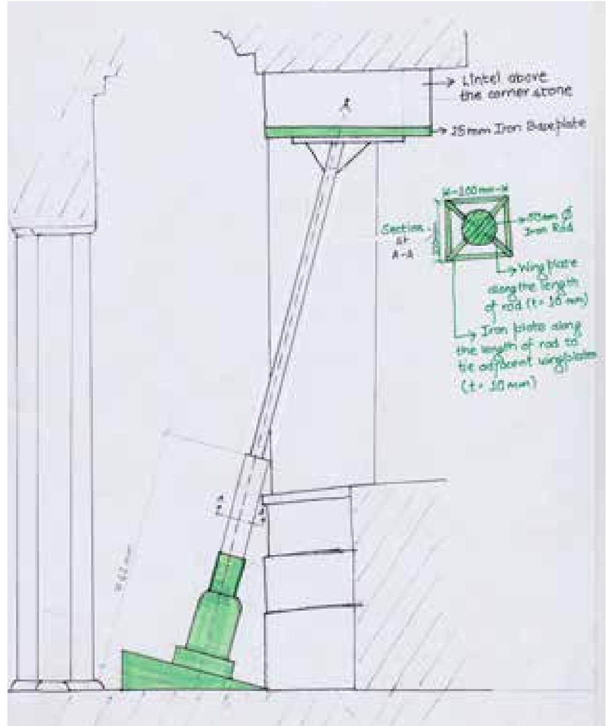
Center:
Shiva Level core survey showing observed areas of bearing to identify load paths and predicted difficulties of corner stone removal.
(Drawing by C. Corallo, January 23, 2017.)

Top Right:
Shiva Level plan showing corner stone elements highlighted in red, and showing how the four corner pieces of the tension ring join to consolidate the structural core and resist dislodgement of stones.
(Annotations by E. Speer, March 2017, Original plan by N. Gutschow)

the finished product is improved over the existing condition. Each column reinstallation was informed and improvised by the team on site based on condition and configuration of existing iron pins and stones at each corner. Interventions sought to retain existing load paths and stone interaction.

Knowing the procedure will be refined for each corner, a baseline procedure was developed and implemented to remove and replace one corner stone at a time. This procedure started with corners presenting least visible risk.

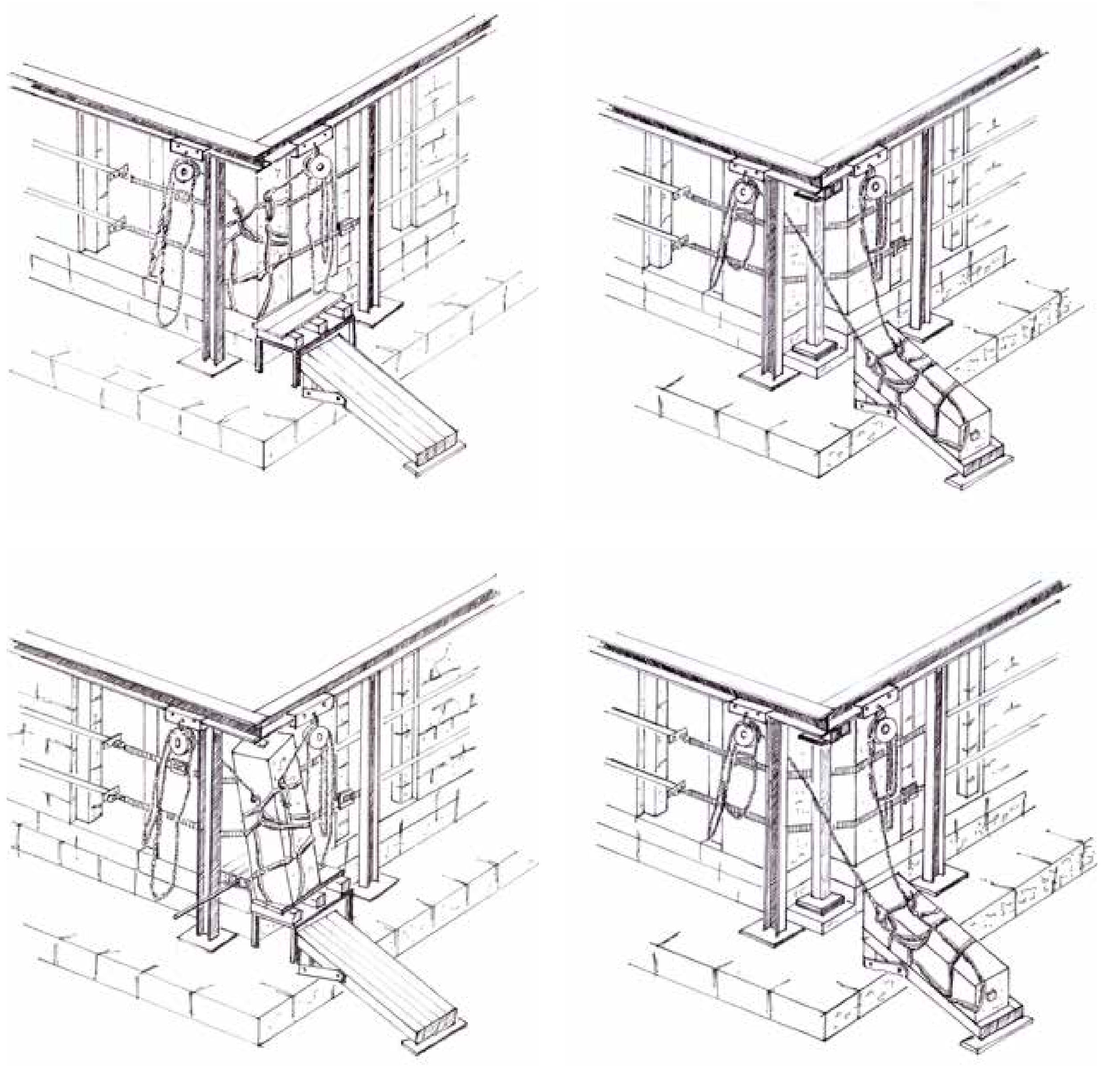
Leaving the corner with the highest amount of visible risk for last, would allow the global structure to be more stable (with 3 repaired corners), to reduce global risks on the structure during the fourth corner's replacement.



Partial building section at the Shiva level showing an early iteration of a jacking procedure to remove bearing weight from the corner stones. This investigation sought to create a thin jacking post mechanism, consisting of a 50 mm diameter steel rod to be inserted into the gaps between stones and secure the upper stones when the corner stones were removed. This idea was abandoned, due to spacing constraints, and concerns regarding shifting load paths while jacking the upper structure in this manner.
(Drawing by P. Hora, December 16, 2016.)

The original procedure, as recommended by consultant Neeta Das et al. was to jack the lintel stone bearing on the corner columns. This would require a metal plate attached to an inclined prop with hydraulic jack bearing on a wooden wedge within the ambulatory outside the core. The props would be inserted in the vertical joints between corner and adjacent stones. This procedure was abandoned because: available hydraulic jacks are difficult to control and jacking could easily transfer loads into other areas introducing new damage to the structure; metal plates inserted into the joints would need to be narrow enough to fit between gaps that are, in some places, narrower than 1 inch. This would mean applying a considerable force to a very small area and possibly inducing localized brittle failure which could put the whole system at risk.
The bearing point of the inclined jacks would not be solid structure down to ground level, so it would require extensive shoring beneath. Also, as engineers, we advise to minimize changes the original load paths of the structure during temporary works. The jacks would introduce a horizontal component, shifting vertical loads.

A new baseline procedure for the first corner stone replacement was chosen, which would not change load paths of the structure during the construction works. This procedure is shown diagrammatically on the following pages:



Southwest Corner Stone Removal Procedure:

Stage 1 - The steel angle belt sections on the corner to be worked on were removed. These were replaced with ratcheting straps, laced behind the corner stone to be removed. The corner stone was wrapped with different straps and connected to two chain pulleys secured to the steel frame in the Shiva level.
(Drawing by P. Amatya, March 2, 2017.)

Stage 2 - The corner stone was carefully removed with wedges and an iron prybar, with the two chain pulleys guiding and sharing the weight of the ~700kg stone. Ratchet straps were tightened continuously throughout the process to retain tension in the straps and to help push the corner stone.
(Drawing by P. Amatya, March 2, 2017.)

Step 3 - The column, now out of its in-situ position, was lowered with the chain pulleys to a small sloped wooden platform which distributed the load on stronger areas of the structure below, so the stone did not bear on thin floor buildups. The sloped platform allowed easy access for masons to work on the structure and to access to all sides of the removed corner stone. Chain pulleys remained in place and tied to the stone for reinstallation.
(Drawing by P. Amatya, March 2, 2017.)

Step 4 - Once the stone was set onto the wooden platform, a steel prop with wooden spacers and shims was inserted to provide to support the upper stones as added protection when the surrounding stones were being repaired. This provided a redundant load path in case an earthquake struck the structure weakened during construction.
(Drawing by P. Amatya, March 2, 2017.)

Top Left:
Southwest corner stone strapped, connected to the chain pulley system and ready for removal. Steel angle belt has yet to be removed.
(Photograph by E. Speer, March 2, 2017.)

Top Right:
Southwest corner stone slowly being removed with chain pulley system.
(Photograph by E. Speer, March 2, 2017.)

Bottom Left:
Surya Bahadur Ranjitkar checking straps on the southwest corner stone as it is removed from its in-situ location.
(Photograph by E. Speer, March 2, 2017.)

Bottom Right:
Pranam Hora orperating one chain pulley as Claudio Corallo observes edge clearance of the corner stone as it is angled to be lowered out of its in-situ position.
(Photograph by E. Speer, March 2, 2017.)

Top Left:
The southwest corner stone successfully removed and placed on its temporary wooden bench.
(Photograph by P. Amatya, March 2, 2017.)

Top Right:
Pranam Hora and Evan Speer operating the chain pulleys as the site team helps guide the southwest corner stone into place atop its temporary wooden bench.
(Photograph by P. Amatya, March 2, 2017 .)

Bottom Left:
The successfully removed southwest corner stone.
(Photograph by P. Amatya, March 2, 2017.)

Center:
Surya Bahadur Ranjitkar with the temporary steel post installed in place of the removed corner stone. Note that the orange ratchet straps are tensioned and acting as the last section of the tension belt to secure the core walls during construction.
(Photograph by P. Amatya, March 2, 2017.)

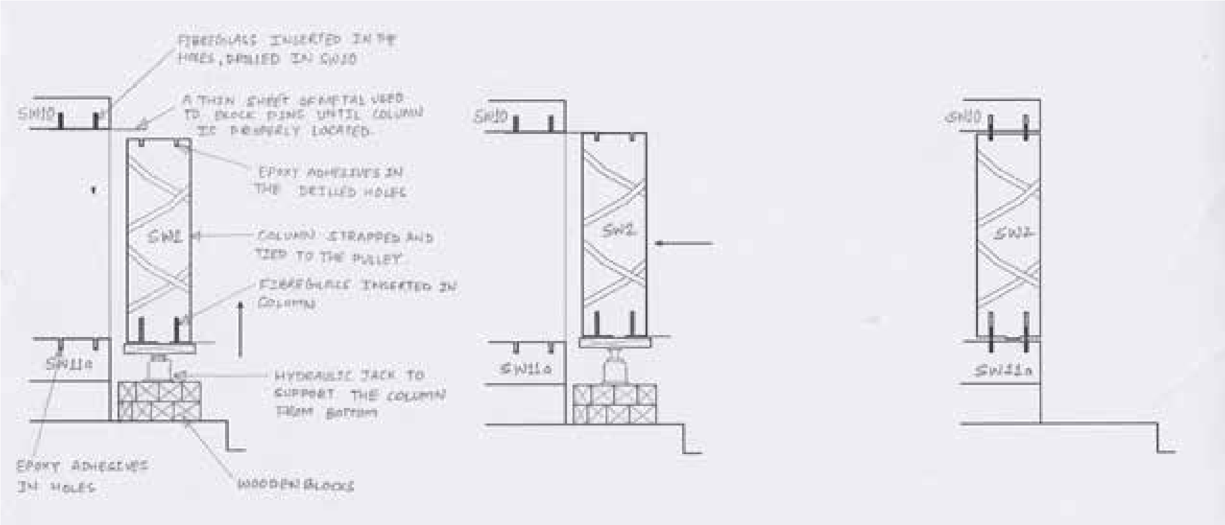
First corner stone (SW) reinstallation:

The southwest corner stone was chosen as the first column to be replaced, because it had the least amount of bearing area (25 cm^2) and had the largest joints allowing easiest access to install the strapping around for removal. The stone was removed on March 2, 2017 per the procedure described in the preceding pages.

The proposed design for the replacement of the column is shown below. This incorporated two dowels both at the top and the bottom of the corner stones, which would be inserted into the upper dowel hole and allowed to drop into place when the corner stone was reinserted.

This procedure was ultimately abandoned by the team on site because the masons did not feel comfortable drilling dowel holes into the upper lintel stones with the available drill machinery - too much vibration induced into the structure, and the site team did not feel confident they'd be able to ensure precise enough alignment to allow all dowels to drop into their positions.

The column was reinstalled on May 30, 2017, and the the final configuration implemented by the site team involved only a single 16mm stainless steel dowel in the base connection, and no added reinforcement to the top of the corner stone. Two 12mm horizontal fiberglass rod dowels were later installed in bed joints at third points from behind to secure into mortar beds of the interior triangular stones, but the capacity and configuration of this connection is not equal to the proposed vertical pin. Horizontal dowels in this configuration will experience tension with the introduction of lateral (horizontal) forces during an earthquake as opposed to shear in vertical pins. This results in a lower strength (dependent on friction between pins and mortar), and changes the behavior of the original structure. But this detail does provide added cohesion to the structure and adds restraint to the corner stone against overturning.



Proposed Southwest Corner Column Replacement Procedure:

Stage 1: Lift the corner stone with the pulley system to bring it vertical. Support the corner stone with a hydraulic jack and jack it to align vertically with the opening.

Stage 2: Push the corner stone into the horizontally place with copper sheet underneath, holding two stainless steel dowels each, inside the column (for bottom connection) and in the upper stone (for top connection). Once in place, the copper sheet was removed to allow the stainless steel rod to drop into place.

Stage 3: Remove the straps from the corner stone as the joints are pointed with mortar.
(Drawing by P. Amatya, April 4, 2017.)

Top Left:
Surya Bahadur Ranjitkar chiseling out a mortise in the base stone to accept tenon from the southwest corner stone in preparation for reinstallation.
(Photograph by P. Amatya, May 30, 2017.)

Top Right:
Surya Bahadur Ranjitkar preparing to point mortar joints after reinstallation of the corner stone.
(Photograph by P. Hora, May 30, 2017.)

Bottom Left:
The southwest corner stone being hoisted back into position by the chain pulleys from its location on the temporary wooden bench.
(Photograph by P. Amatya, May 30, 2017.)

Center:
Successfully reinstalled southwest corner stone with the steel angle tension rings reinstalled. Horizontal joints above and below the column were set in mortar on the day of reinstallation, while vertical joints were repointed at a later date.
(Photograph by P. Hora, May 30, 2017.)

Top Left:
Altered removal procedure for the northeast corner stone involved placing it vertically on a bench to limit complexity of reinstallation.
(Photograph by P. Amatya, July 12, 2017.)

Center:
Once the northeast corner stone was removed, temporary wooden posts were installed in its place.
(Photograph by P. Amatya, July 12, 2017.)

Top Right:
Surya Bahadur Ranjitkar inserting 16 mm stainless steel dowel into hole in corner stone base to allow dowel to drop into hole in base stone.
(Photograph by A. Basukala, July 23, 2017.)

Bottom Right:
Surya Bahadur Ranjitkar drilling hole for 16 mm stainless steel dowel at base connection.
(Photograph by A. Basukala, July 23, 2017.)

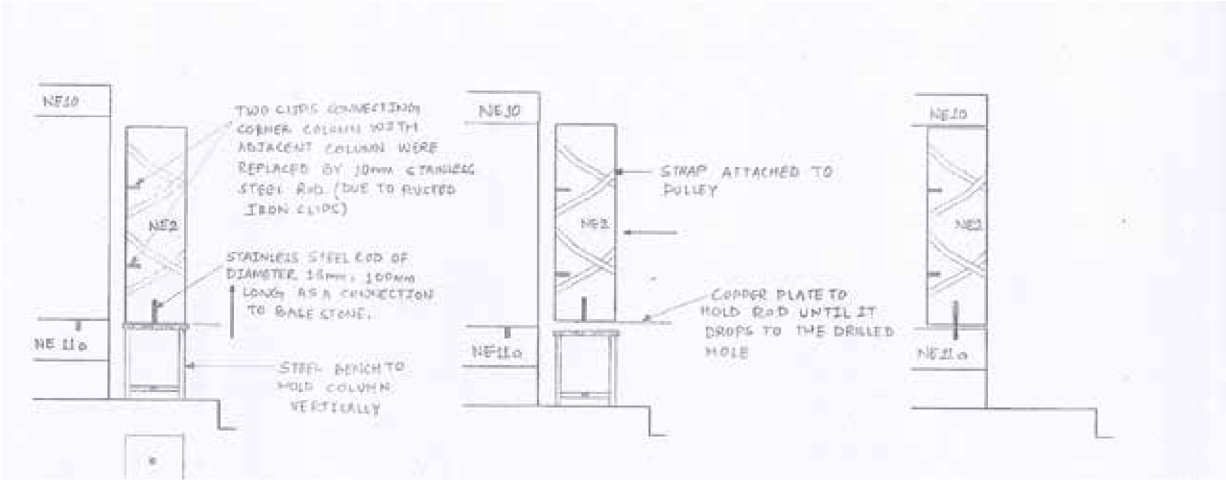
Second and third corner stone (NE, SE) removal and reinstallation:

When designing the procedure for the second and third corner stone removals, the procedure was changed to simplify the procedure by shifting the column out of its existing location and to leave it vertical, resting on a small steel bench just outside of its original location. This was conducted to limit the swinging of the stone during removal, and reduce the risk of it causing damage to nearby stones during removal and replacement. The most challenging issues in the first corner stone removal was positioning and moving the approx. 700 kg corner stones out of the existing location to its resting place.

The reinstallation procedure of the second and third corner stones can be seen in the graphic on previous page.

The existing configuration of the flat iron pins was ultimately recreated with 10mm stainless steel pins by the site team. As there was no dowel inserted into the top face of the stones, the stainless steel pins inserted should have been larger than 10mm to provide added corrosion resistance and tensile strength to hold the corner stones against movement.
Vertical dowel holes at the base of the corner stones were tapered with a drill to allow for easier alignment of the dowel holes.

Northeast corner stone removed on July 12, 2017.
Northeast corner stone reinstalled on July 23, 2017.
Southeast corner stone removed on September 5, 2017.
Southeast corner stone reinstalled on September 11, 2017.



Top Left:
Newly installed base stone with oversized hole to accept 16 mm stainless steel dowel.
(Photograph by A. Basukala, July 23, 2017.)

Top Right:
Reinstalled northeast corner stone.
(Photograph by A. Basukala, July 23, 2017.)

Bottom:
Northeast Corner Stone Replacement Procedure:

Stage 1: The corner stone was placed vertically on a steel bench immediately after its removal with chain pulley system.

Stage 2: The corner stone was pushed horizontally into place with a copper sheet underneath, holding a 125 mm long, 18 mm diameter stainless steel dowel inside the corner stone. Once in place, the copper sheet was removed to allow the stainless steel rod to drop into place.

Stage 3: The straps were removed from the corner stone as the joints were pointed with mortar.

Note: Only one stainless steel rod was inserted into the corner stone by the site team, as it was judged that the corner stone's cross-sectional area was too small, and included a cracked corner, to support multiple dowels.
(Drawing by P. Amatya, August 17, 2017.)

Top Left:
The northwest corner stone was bearing more structural weight on less bearing area than the other corner stones. The precarious position is seen, with wood propping that had been mandatory after the soft base stone had blown out during the earthquake.
(Photograph by L. Batty, October 23, 2017.)

Center:
After additional propping and shoring was installed, Surya Bahadur Ranjitkar drilled and chiseled portions of the base stone to loosen the corner stone and allow for removal.
(Photograph by L. Batty, October 23, 2017.)

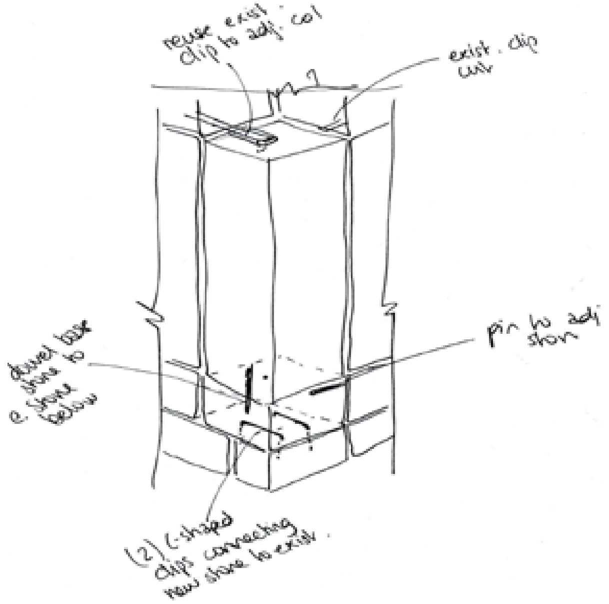
Right:
Field sketch denoting as-built layout of the reinstalled northwest corner stone with new and existing clips, pins and dowels securing the newly installed base stones and corner stones into place. All new elements introduced were stainless steel elements.
(Field Sketch by L. Batty, November 2, 2017.)

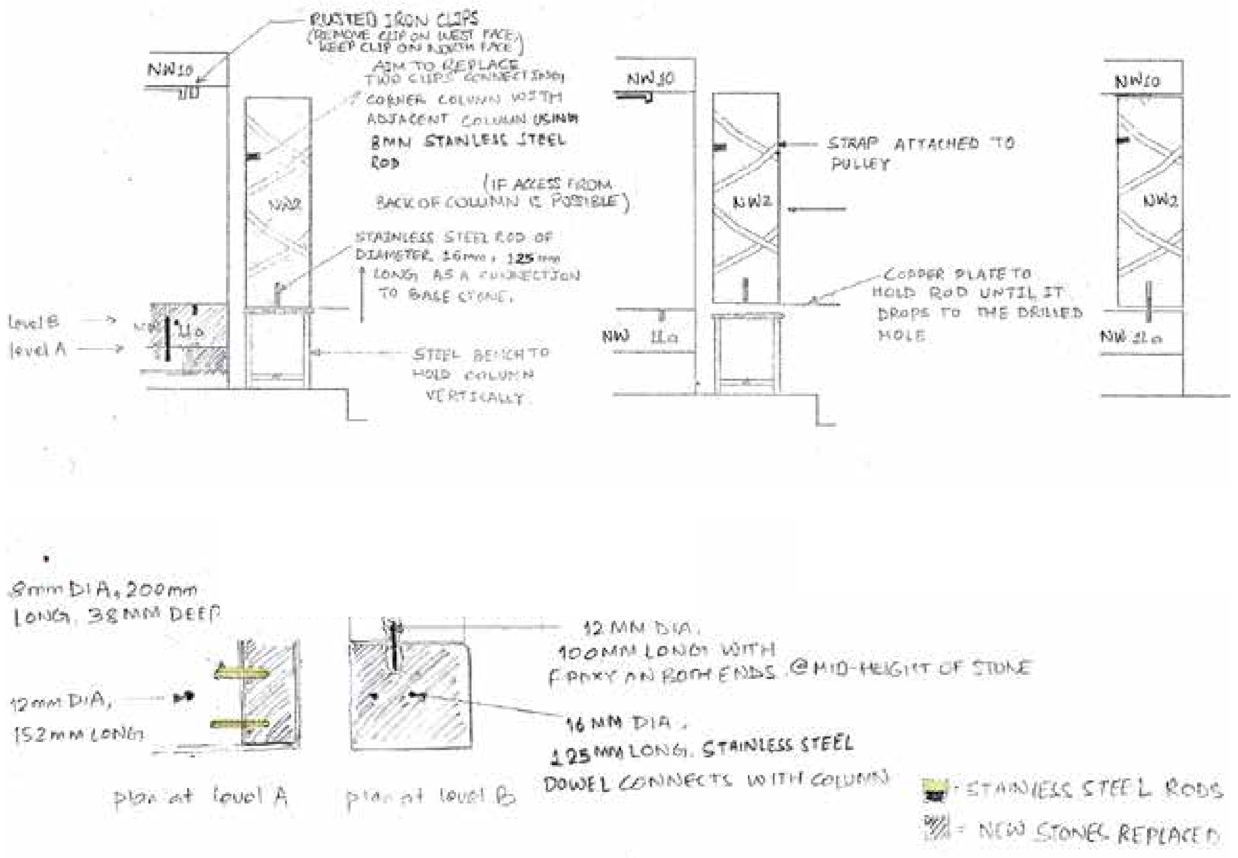
Fourth corner stone (NW) removal and reinstallation:

The northwest corner stone was left for last because this stone presented the highest visible risk for multiple reasons. The base stone beneath the corner stone had experienced extensive spalling and loss of section and was only supporting about 50% of the corner stone. The triangular stones which line the sanctum inbound from the corner stone and also support the lintels were found to be load bearing in this corner, while not in the other corners.

For removal of the corner stone, a small wooden trestle was installed around the corner to support the column under its base. Additional raking shores were installed on the stone above the corner stone on the west side. The interior triangular stones were left, as they were in bearing, and a small shore was added under the uppermost triangular stone to add support. Additionally, loose stones at the northern entryway were removed and a vertical post added, so that there is bearing for the stone above and these stones were not damaged during removal of the northwest corner stone. Masons then slowly chipped away at the base stone, beneath the column, to free up the column for removal. Upon removal, the existing pin configuration was observed and the securement strategy was addressed, as seen in the graphic below. Due to some miscommunication and a lack of locally available materials, the site team chose stainless steel dowels in lieu of the recommended fiberglass rods in many locations.

Northwest corner stone removed on October 23, 2017. Northwest corner stone reinstalled on November 2, 2017.





Left:
Northwest Corner Column Replacement Procedure:

Stage 1: Corner stone was placed vertical on a steel bench immediately after its removal with chain pulley system.

Stage 2: Corner stone was pushed horizontally into place with a copper sheet underneath, holding a 125 mm long, 18 mm diameter stainless steel dowel inside the column. Once in place, the copper sheet was removed to allow the stainless steel rod to drop into place.

Stage 3: The straps were removed from the corner stone as the joints were pointed with mortar.

Note: The site team chiseled off the 100 mm x 100 mm x 15 mm tenon due to lack of a vertical gap in which to reinsert the column.
(Drawing by P. Amatya, November 3,2017.)

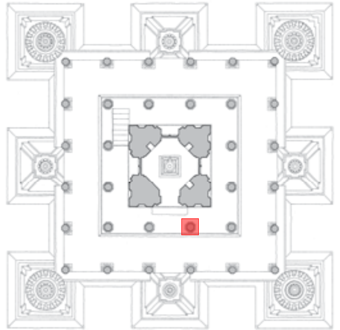
Right Top:
Pooja Amatya observing the condition of the northwest corner after the corner stone had been removed.
(Photograph by L. Batty, October 23, 2017.)

Bottom:
Column view from the Southeast, and location of column S3 denoted in key plan.
(Original plan by N. Gutschow.)

Center:
Bearing condition of column S3 showing loss of section and spalling of the outer surfaces, evidence of weakened stone and rocking during the April 25, 2015 earthquake. The column currently bears on approximately 50% of its original cross-section.
(Photo by P. Amatya, July 13, 2016.)

Right:
Elevation of freestanding stone column S3, seen from the southeast. This column experienced substantial damage and loss of section during the 2015 earthquake.
(Photo by P. Amatya, July 13, 2016.)

Facing Page
Cross bracing is being added to the scaffolding for transferring the new stones to the Shiva temple level.
(Photo: KVPT, Mar 20, 2017.)



Column Vulnerability

Within the inner colonnade, positioned just outside the ambulatory adjacent to the core of the Shiva level, there was substantial evidence of movement in the past. These columns, as much of this structure, rely on bearing load and friction to maintain their load paths. During an earthquake, the combination of horizontal and vertical loads result in rocking motion that allows connections between these elements to shift. This dissipates energy and can lead to reduced damage during smaller earthquakes, but also the randomness of earthquake loading means that this does not prevent the risk of collapse.

Many of the 20cm (8”) octagonal columns experienced movement during the earthquake and do not properly align with the capital elements. Some capitals experienced loss of section, and one column in particular, on the south line of the inner colonnade, one column experienced extensive damage. It is stipulated that this column was likely made with a lesser quality stone, and its origin is unknown.

Loss of section of the column, combined with being out-of-plumb, means that this column must be replaced. A replacement to this type of column should include a vertical fiberglass or stainless steel dowel extending from the beam to bracket to capital to the column shaft, and also from the column shaft to the base. This would allow the energy dissipation of the rocking of stone elements, but would retain the load path and resist the dislodgement of the stone elements by providing vertical continuity.

There was hesistation in the site team to replace this column, due to concern about the shoring and relieving the load. In January 2018, the team on site proposed to patch the octagonal column as a temporary measure, but ultimately the column should be replaced.

Chapter 5:

Structural Restoration

The restoration of the temple included three major problems ; those that were structural, those that were non-structural, and some that could be termed as housekeeping and ornamental. The structural problems were due to the earthquake. It would seem that this temple was probably designed for earthquakes. If one looks at the arrangement of stones carefully, the *garbha griha* is octagonal in plan with a domical roof. The roof rests on a ring beam which in turn rests on lintel beams. The lintel beams are transferring the load to stone walls. The four corner stones are left largely free of the structural system, probably designed to 'fail' during an earthquake.

It is only these four corners and columns that have been most severely damaged but their repair was simpler since they did not support the upper structure. The temple had been severely damaged at the Shiva level. The lower Krishna level and the ground floor were more intact. At the second floor Shiva level several columns had been dislodged and were out of plumb due to the seismic stresses. Capitals, shafts, and brackets of the columns were broken and needed attention. Keystones and other stone members of the openings had been dislocated or had fallen off. Cracks had appeared in many places. All the problems, identified above, had to be attended immediately to prevent collapse of the upper portion of the building.

The other problems in the temple which were an outcome of the earthquake, although non-structural in nature, needed immediate attention. These primarily included the loss of pointing between stones. The joints were thus exposed and water made way through these cracks. Some pointing was damaged due to age. Other pointing was removed and had to be re-pointed due to its unsightly appearance. Pointing was done in the interior walls, floors, *chatris*, and the exterior walls. Stones damaged due to earthquake, age, and wear and tear, were replaced with new stones as and where needed.

Since the temple was being restored it made sense to do some repair and maintenance of the same. The ground floor plinth was cleaned and missing and broken stones replaced; the staircases , where the treads had worn out were repaired; and the statues , covered with vermilion, were cleaned. The metal door of the *garbha griha* repaired, cleaned, and re-installed. A team of experts from Austria re-pointed the *shikara* , replaced damaged stones of the *shikara*, and restored all the metal ornaments of the temple. Finally a German team designed the night time decorative lighting for the temple.

Facing Page
Second (Shiva Level) Floor was most affected by the Earthquake.

Left
Joints of the floor were re-pointed.

Right
Stone Joints of the *chatris* were re-pointed.

Left
The damaged Krishna level balcony floor joints, paved with stone is being carefully taken out for repair.
(Photo: KVPT. June 24, 2018)

Center Top
Water seeped in through the open joints of the *chatris.*

Center Bottom
Finished floor of the Shiva level after re -pointing.

Right Top & Bottom
Loose stone joints were visible before restoration. they were re-pointed after the metal pinnacles were cleaned and replaced.

Left Top
Old damaged stones replaced with new carved stone.

Left Middle
Damaged stone in the ground floor plinth.

Left Bottom
Old damaged stones were replaced.

Center Top
Carved stones of the Krishna temple worshipped with vermillion.

Center Bottom
The armature of the metal pinnacle being removed for restoration.

Right
Stone mason Asha Bahadur Ranjitkar making new stone *nagol* to replace the damaged ones.
(Photo: KVPT. June 03, 2018.)

Left Top
Stone Mason Surya Bahadur sizing the stone for the staircase steps to replace the damaged once. (*Photo:KVPT. July 01, 2018*)

Left Bottom
Staircase of the Krishna temple after repair.

Center Top
Stone statues of the Krishna level being cleaned.

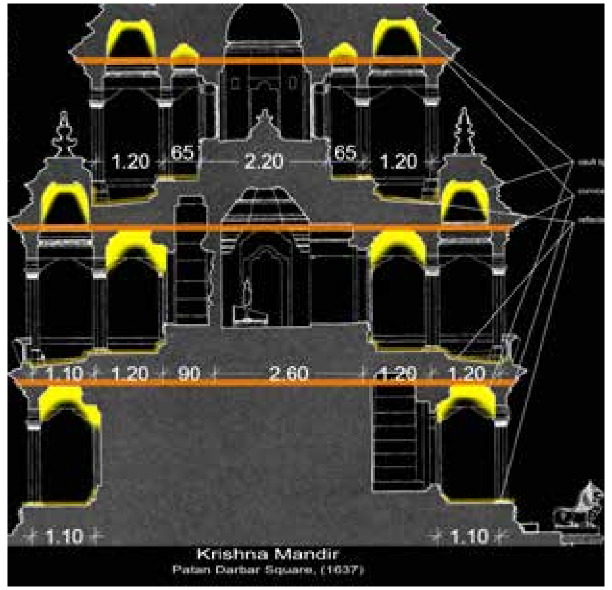
Center Bottom, Right Top & Bottom
Open joints of the *shikara* being re-pointed by the Austrian team.

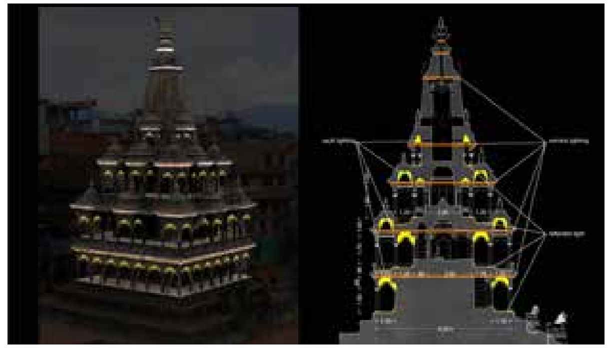
Left Top
The Austrian team had set up a small workshop for the restoration of the metal members of the Krishna temple.

Left Middle & Bottom
Missing and damaged stone pieces of the *shikara* were replaced by the Austrian taem.

Right Top
Austrian team members restore the pinnacle of the *chatris.*

Right Bottom
Ingredients for preparation of mortar for the pointing of *shikara.*





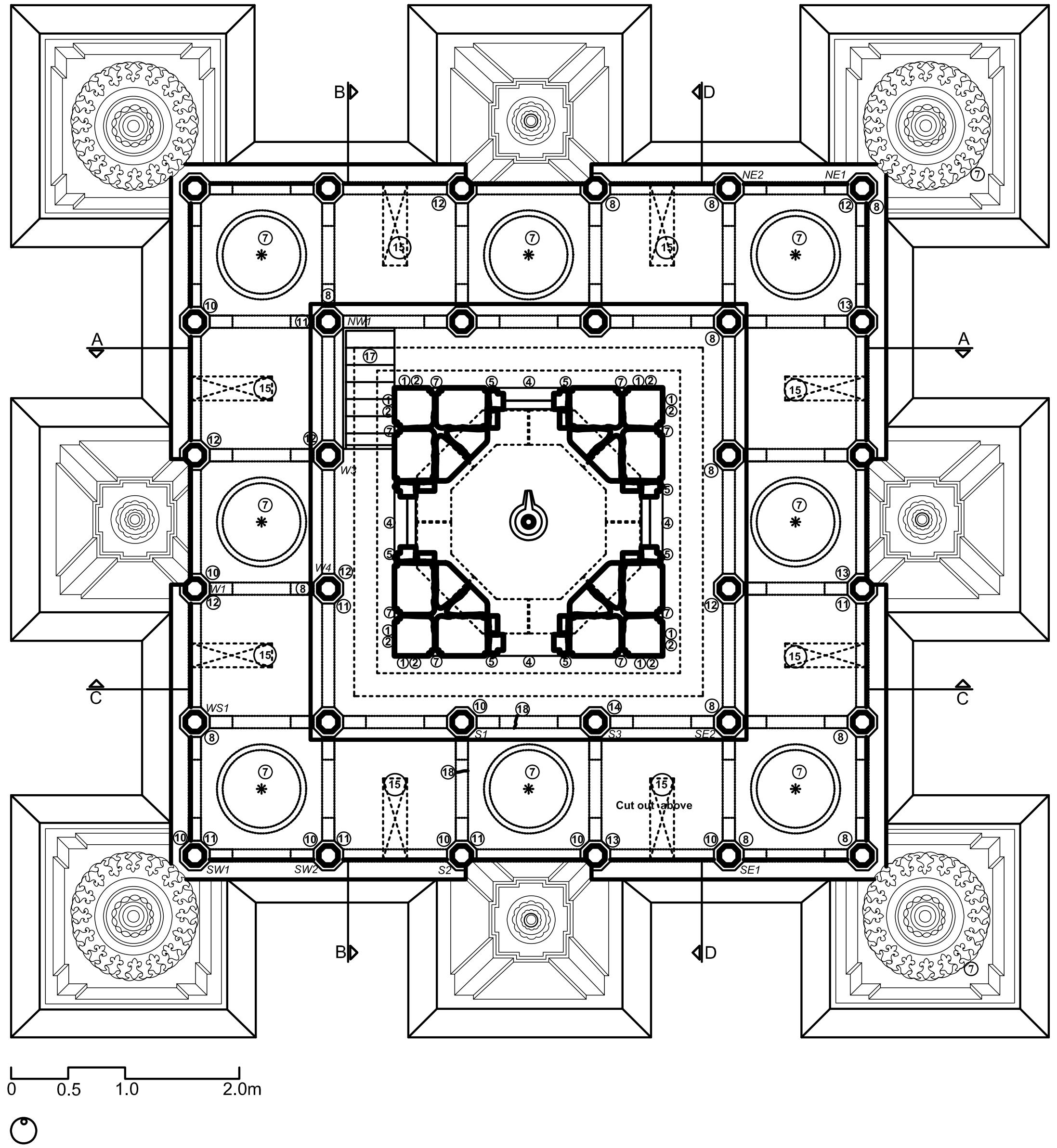
Left Top
The deteriorated and damaged stones of the main entrance step.
(Photo: KVPT, July 01, 2018.)

Left Bottom
The damaged stone steps of the main entrance of the temple have been replaced with new ones.
(Photo: KVPT, July 06, 2018.)

Center
Members of the Austrian team restoring the pinnacles.

Right Top
Structural parts of the metal pinnacles.

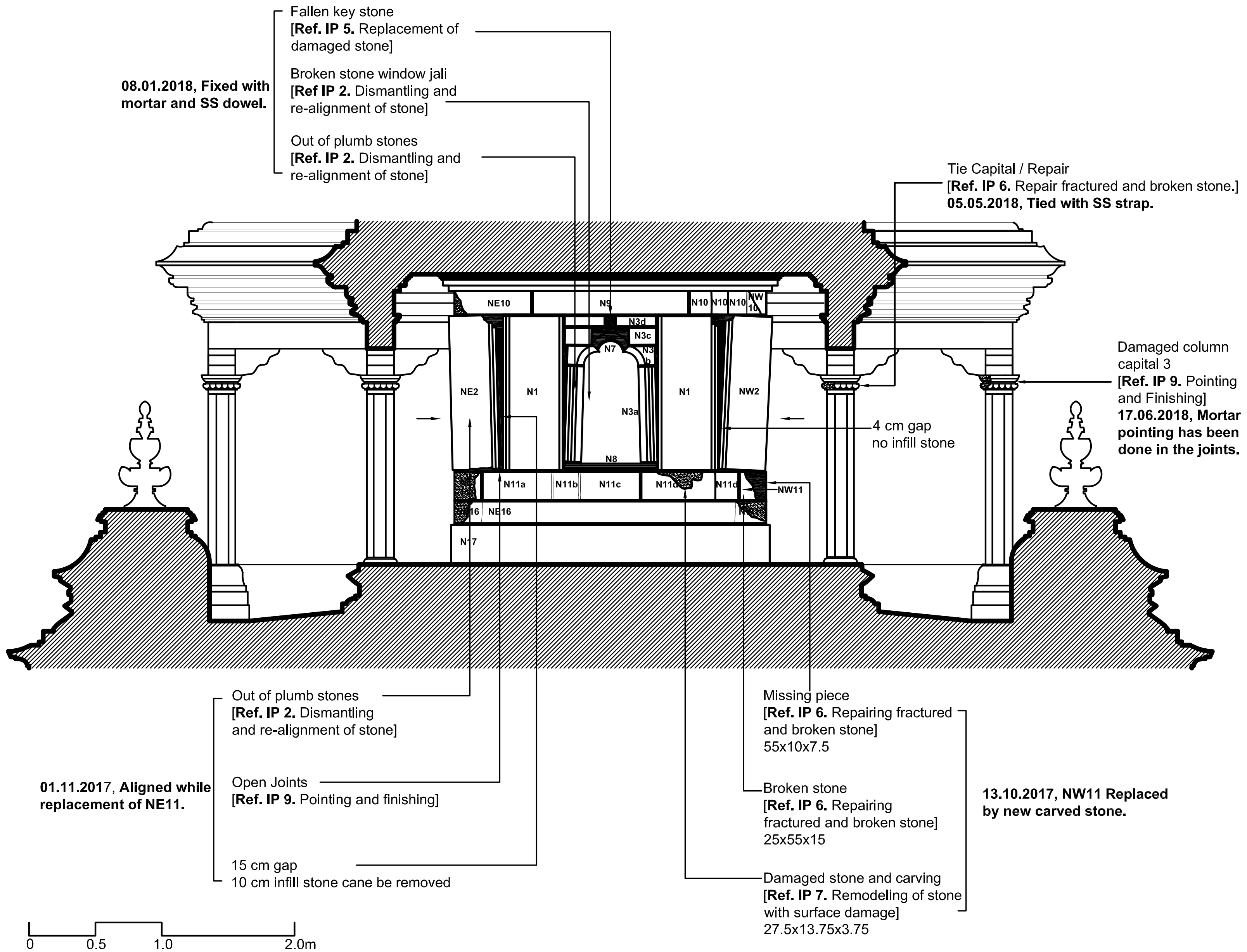
Right Middle & Bottom
Proposal by Alelier Rang from Germany to illuminate the Krishna temple.



Second Floor Plan Drawing Indicating Damage and Reference Numbers For Photographs

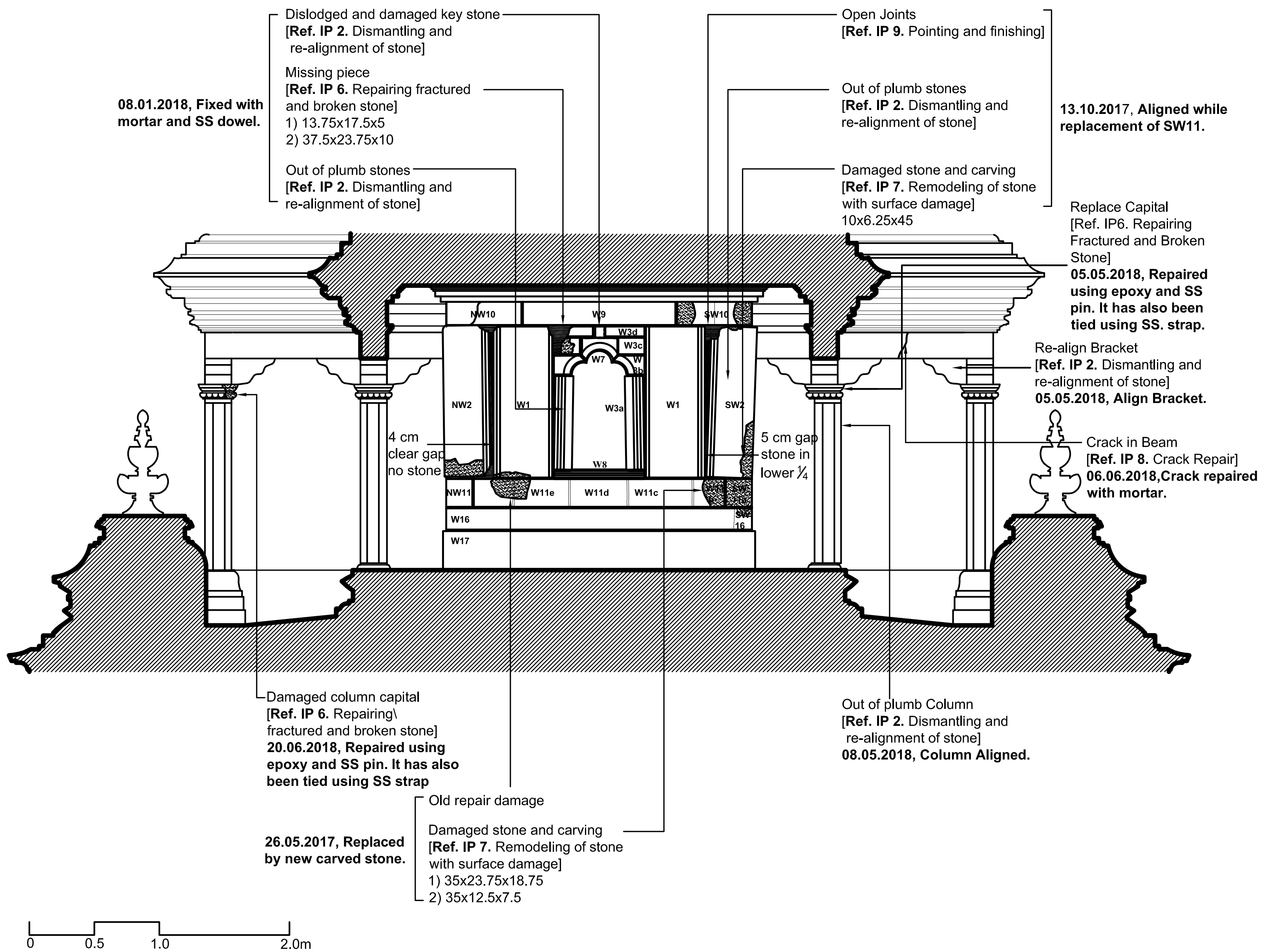
Drawing by Nilufa Rahman and Suchismita Bhattacharya, 2016

Identification of Damages	
1.	Damaged and out of plumb corner stones of garbha griha
2.	Damaged stone and carving
3.	Damaged stone
4.	Dislocated/Fallen key stone
5.	Dislodged window frame
6.	Loose /Broken stone window jaali
7.	Open joints
8.	Old repair damage
9.	Cleaning of garbage and stacking archaeological remains
10.	Out of plumb columns
11.	Dislocated brackets
12.	Damaged column capital
13.	Damaged column base
14.	Damaged column shaft
15.	Tin shed addition
16.	Damaged pointing in all floors
17.	Damaged tread stones in staircase
18.	Crack in beam
19.	Damaged pinnacle



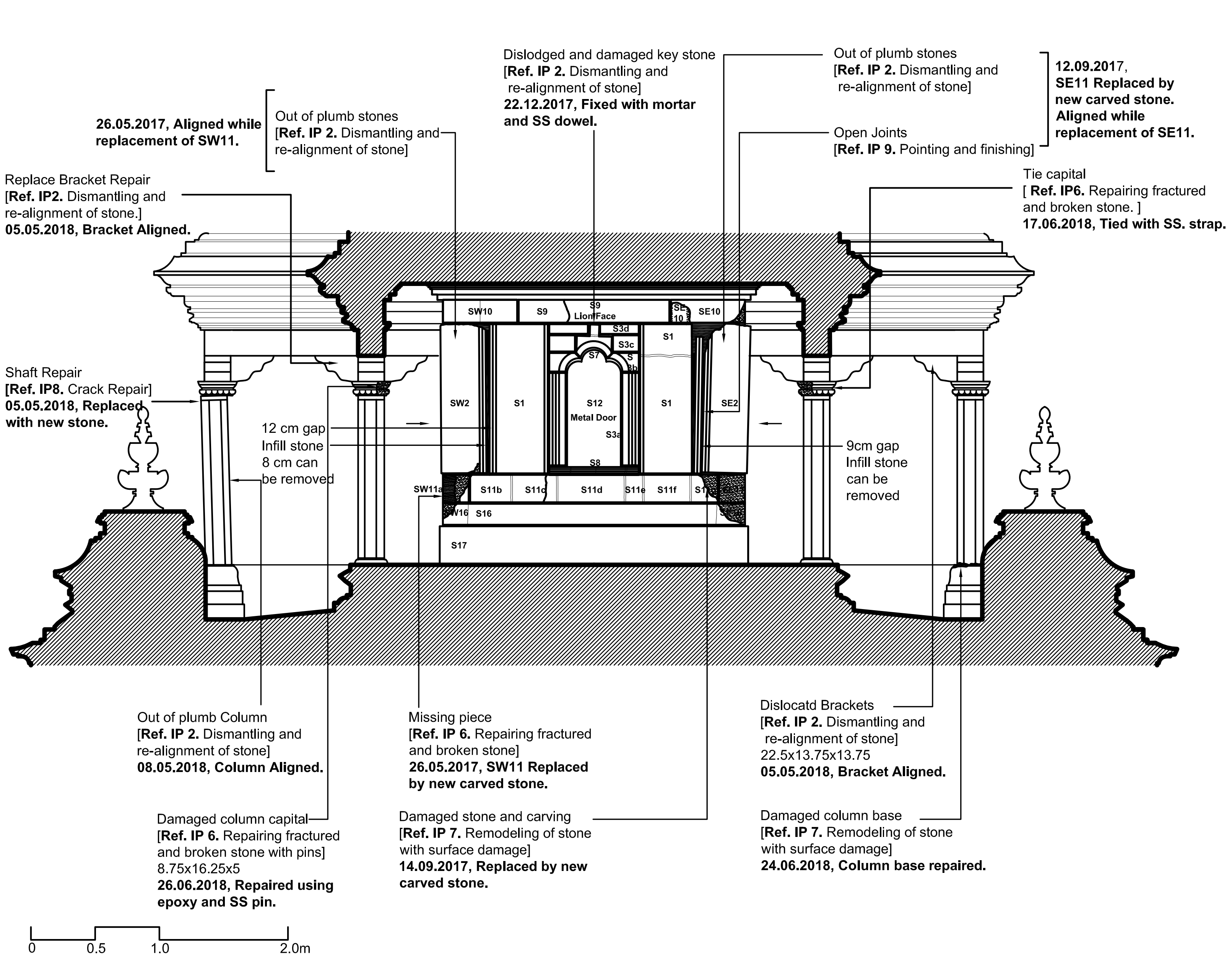
Indicating Damage and Details of Repair on North Face
Drawing by Nilufa Rahman & Suchismita Bhattacharya, 2016

North Side Sectional Elevation AA



Indicating Damage and Details of Repair on West Face
Drawing by Nilufa Rahman & Suchismita Bhattacharya, 2016

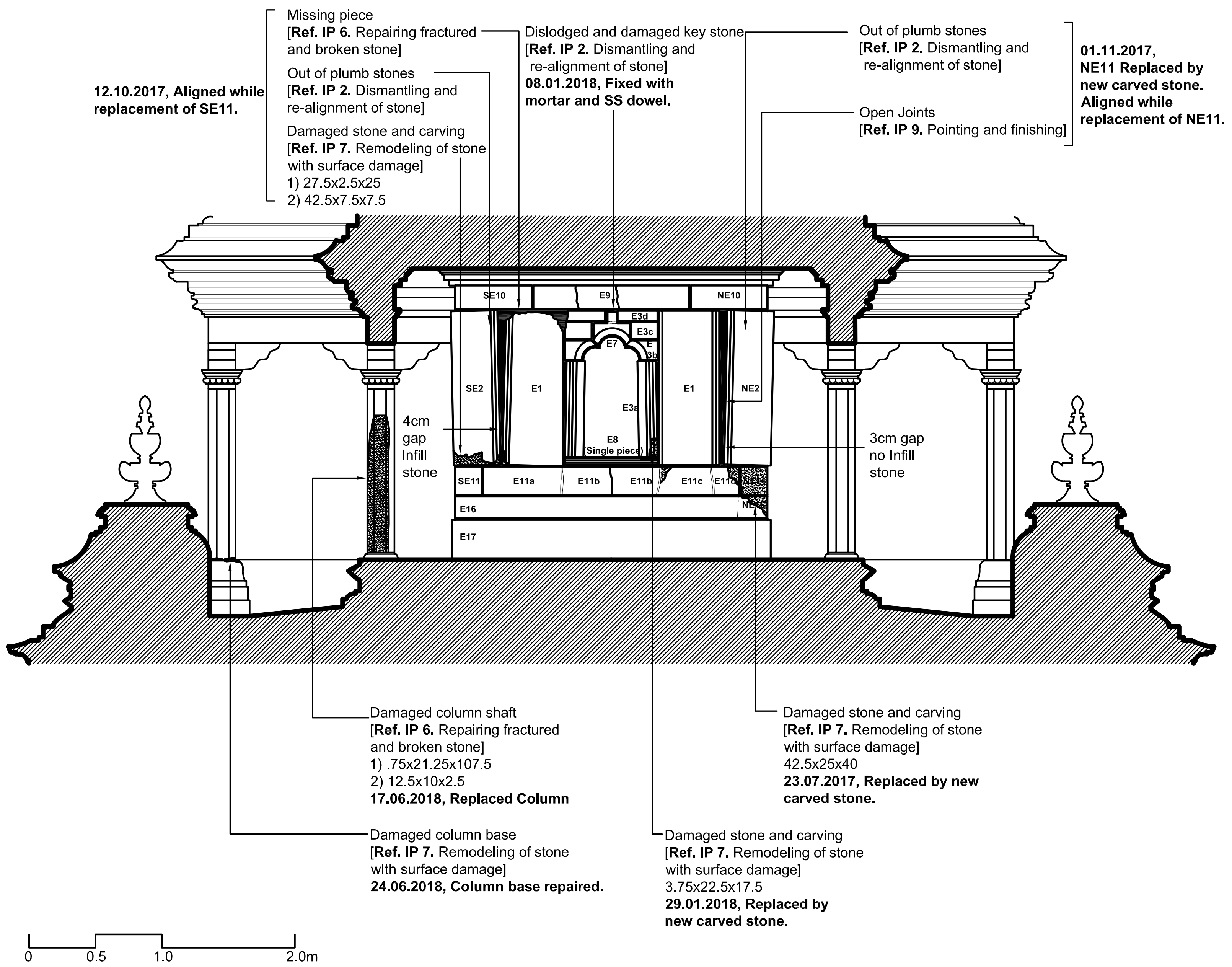
West Side Sectional Elevation BB



Indicating Damage and Details of Repair on South Face

Drawing by Nilufa Rahman & Suchismita Bhattacharya, 2016

South Side Sectional Elevation CC



Indicating Damage and Details of Repair on East Face

Drawing by Nilufa Rahman & Suchismita Bhattacharya, 2016

East Side Sectional Elevation DD

Below
South-east, North-east, South-west, and North-west corner stones after restoration.

Facing Page
Left & Center
Damaged corner stones before restoration and the wooden prop to support the unstable north-west corner.

Right Top
The four pieces of lower corner stones at the south west corner are first assembled for trial to ensure proper fit.
(Photo: KVPT, May 24, 2017)

Severely damaged corner stones

Some stone have been severely damaged and could not be repaired. Among these were the four corner stones, as mentioned above. The stones at the plinth level of these corners were most damaged. The damage was severe in all the four corners. The vertical monolithic stone columns were out of plumb and the eccentric loads from above seemed to have damaged the stones below. Large chunks of pieces had fallen off not giving the column enough base support to rest thus making them unstable. Since the stones had been reduced in size and shape, they had to be replaced by new carved stones .

Before any work was done the un-stable stones had to be propped and braced for the safety of the workers. It was recommended that the areas be inspected carefully and a judgment made on the method of dismantling. It was also recommended that proper machinery be used for this and care was to be taken so as not to damage the stone further. Temporary protection like bubble wrap and foam sheets were recommended to be tied around the stone to prevent crushing of edges during dismantling. The same precautions were to be taken while erection of repaired or new stone. Stone had to be replaced with a similar stone matching in property and colour and fixed as recommended.

Right Center and Bottom
16 mm stainless steel bar has been added for reinforcement
(Photo: KVPT, Sept. 08, 2017)

Left
Close up view of carving details on the stone tympanum of all portal.
(*Photo: KVPT. Jan 11, 2018*)

Damaged carved and un-carved stones

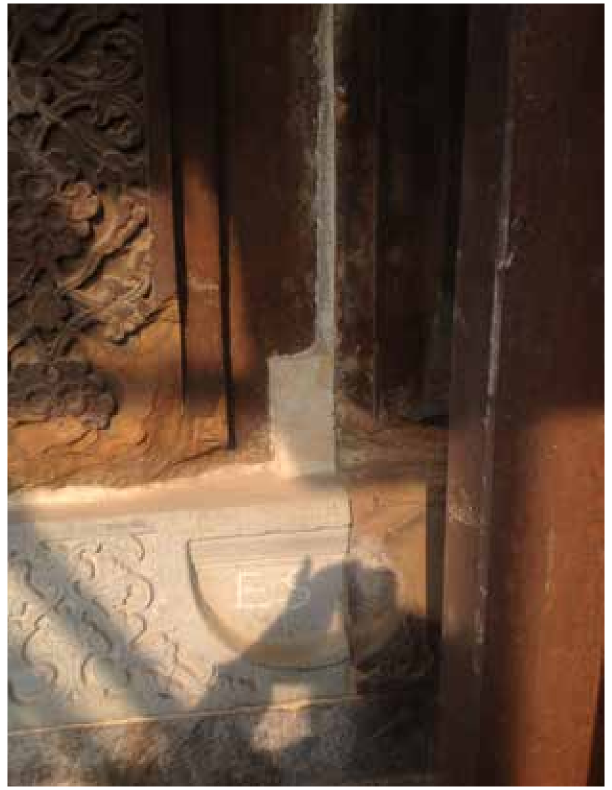
There are not as many carved figures or figures in relief in the Shiva temple as in the first floor which is the Krishna level. However, the outside wall of the *garbha griha* is ornamented with floral and other patterns. As the corner stones moved, they also disturbed the carved stone lintels above them. Some of the lintel stones were chipped off or damaged. Barring at one place, where a new stone had to be inserted, most of the repair was surface repair and ornamental in nature. Some new pieces of un-carved stone had to be inserted where needed.

It was decided that remodeling of stone for surface damage would be avoided. If very necessary, it may be done sparingly with a restoration mortar (artificial stone) and matching pigments from a reputed company (CTS Templum Stucco, Remmers Restoration Mortar CF) after consolidating the surface and with proper reinforcement. However, it was recommended that this be done by an expert artist and restorer only. If there was no structural distress, it would be advisable not to do any intervention.

Large openings and joints

Due to the movement of the corner stones away from the load bearing stone walls, large gaps could be seen. The core behind the outer wall became visible. Old repair mortar of lime and *surkhi* (brick powder) crumbled out of the open joints. Old repair stone pieces and layers became evident. Since there was no way to inspect the brick core, if any, behind the stone walls, ultra sonic tests were conducted. However, in the absence of proper vantage points for the placements of the nodes, the tests were non-conclusive. Much later, during repairs, when the inner stone wall was opened, no brick core was revealed, flouting the earlier theory.

It was recommended to rake out the old joint carefully by hand in order to avoid damage to the stones. The depth of pointing was to be sufficient to hold the new mortar. Correct tools were to be used for this. It was recommend to flush out the open joint with a jet of clean water, damp it down, and fill with compatible lime mortar as advised. If the joint was too big, some aggregates or stone pieces, of matching colour and properties, were to be inserted to reduce cracking on drying. Care was to be taken to avoid any spilling of the mortar on the stone surfaces to prevent staining. Colour, texture, and thickness of the mortar was to match the original mortar. Natural pigments could be used to give the correct colour. Proper curing was to be done after application.



Left
The gaps between the stones were filled with mortar and new stone pieces.

Center
Due to the movement of the corner stones large gaps were visible.

Right
Pieces of carved lintel stone displaced during earthquake.

Facing Page

Center
New stone carved and replaced in lintel.

Right Top
Original but displaced carved lintel stone re-used and fitted back in place.

Right Bottom
New but uncarved stone used to fill in the gap by a missing stone piece.

Dislocated key stones and door jambs

The *garbha griha* has four openings, one on each side. Three of these are windows with stone *jaalis*, or screens. The opening on the north side has a metal door, with a similar design as the window screens. Due to the movement of the corners, the key stones of the door and window openings had been dislocated or fallen down. But luckily all the key stones, which are made from carved single piece stone, except if repaired later, were intact. They could thus be reused.

It was recommended that all the pieces be collected, marked, and stored in a safe place. The safest place found was the *garbha griha* where all the broken stones were kept. The next step was to brace and support all the openings to prevent further damage. These braces were of wood to protect the carved stones from chipping. After the corners were repaired, the openings were

Left
The opening of eastern portal fitted with one single piece of intricate stone lattice panel.
(Photo:: KVPT. Jan 11, 2018)

Center & Right
Fallen keystone on the North face of the *garbha griha*.

supported and the stones pieces slowly removed and placed in position. This was done from both the inside and outside of the opening. The joints were stainless steel pins, compatible mortar as per specifications, and a strong stone adhesive, as and where needed. The metal door was cleaned, repaired, and replaced in position. As were the stone window *jaalis*.

Left
Keystone on the South face of the *garbha griha* and the *linga* restored.

Center Bottom
Restored West face of the *garbha griha*.

Center Top & Right
Dislocated keystones on the openings of the *garbha griha*.

Left Top
Restored opening on the east face of the *garbha griha.*

Right Top
Restored opening on the north side of *garbha griha.*

Left & Right Bottom
Inner east face of the *garbha griha* before and after restoration.

Left Top
Stone mason Surya Bahadur Ranjitkar repairing the dislocated keystones above the eastern portal.
(*Photo: KVPT. Dec 17, 2017.*)

Center Top
Surya Bahadur Ranjitkar repairing the southern portal.
(*Photo: KVPT. Dec 20, 2017.*)

Left & Center Bottom
Inner north west wall of the *garbha griha* before and after restoration. It had to be dismantled completely before restoration.

Right Top
View of the eastern portal before repair. The keystones above the portal had fallen off during 2015 earthquake
(*Photo: KVPT. Dec 15, 2017.*)

Left Bottom
Stonemason Surya Bahadur Ranjitkar installing the south metal door on Shiva Level.
(Photo: KVPT. May 28, 2018)

Left Top & Right
South inner face of the *garbha griha* before and after restoration.

Left & Right Bottom
The stone *linga* was partially damaged due to the earthquake. Image of the *linga* before and after restoration.

Right Top
Stonemanson repairing damaged Shiva Linga.
(*Photo: KVPT. June 18, 2018.)*

Left Top
Masons Siddhi and Mangal Maharjan pointing column joints after realignment
(*Photo: KVPT. May 20, 2018.*)

Left Bottom, Center & Right
Much of the old repair was damaged after the earthquake and had to be re-pointed in the column capitals, base, and the other places too.

Old pointing repair damage

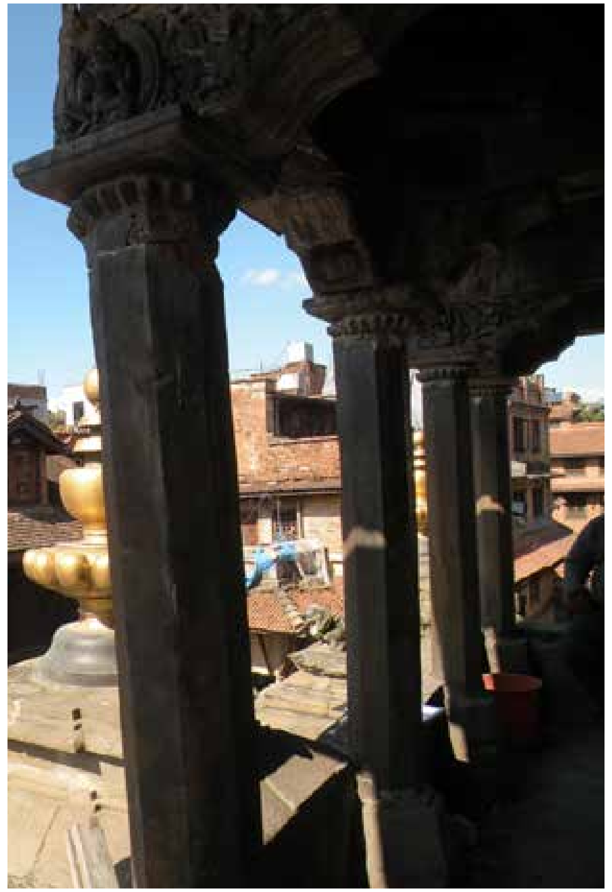
Due to the lateral movements of the temple during the earthquake, the building stones had been displaced from their position leaving their joints open. The mortar and pointing had fallen off. During the last restoration work done, all the joints were sealed by a grey restoration mortar. Most of this pointing had fallen off. Water ingress in other areas also showed that the joints had opened allowing water to come in. There was a great need for sealing all the joints again.

It was recommended that the old pointing be carefully removed by hand or manual tools in order to avoid damage to the stone and the depth be sufficient to hold the new mortar. Correct tools be were used for this. After flushing out the open joint with a jet of clean water, damp it down, and filled with compatible lime mortar as advised. If the joint is too big, some fine aggregates could be inserted to reduce cracking on drying. The grain size of aggregate was not to be larger than 1/3d the thickness of the joint. Care was to be taken to avoid any spilling of the mortar on the stone surfaces to prevent staining. Colour, texture, and thickness of the pointing was to match the original pointing. Natural pigments could be used to give the correct colour. Proper curing was to be done after application.

Out of plumb columns

The *garbha griha* is enclosed by two colonnades. The inner colonnade has twelve slender columns and the outer colonnade has twenty slender columns. All columns have a base, shaft, and capital. The beams above are supported on brackets. Due to the lateral movement of the temple during the earthquake, the columns had tilted and were out of plumb . All tilted columns had moved outwards. Seven out of twenty columns on the outer colonnade had tilted, three on the west and four on the south. Columns on the north and east had not moved at all. Only one column of the inner colonnade on the south side moved, also on the outside.(See Plan)

It was recommended to first brace the columns to prevent any accident. The columns were then to be straightened with the help of a pulley. Temporary protection like bubble wrap and foam sheets were to be tied around the stone to prevent crushing of edges during this procedure. The stone columns were then to be fixed to the bases and capitals with steel pins, mortar, and adhesive as found necessary. Once this was done, the structural system of the temple would become safe.



Left & Center
Out of plumb columns before and after re-alignment.

Rigt Top
The column next to northeast corner, on thew north side, has moved out of plumb by 3 inches.
(*Photo: KVPT. June 20,2017)*

Right Bottom
All outer column from Shiva level being brought to plumb line.
(*Photo: KVPT. May 14, 2018.*)

Left Top & Bottom
Bracket on the west was re-carved and replaced in position.

Right Top & Bottom
Bracket on the south side re-aligned and restored in place.

Dislocated and damaged brackets

All beams were supported by brackets made of a single piece of stone. When the columns and the rest of the structure moved, the brackets became loose, as the load above was not sufficient to keep them immobile. These brackets thus twisted in various directions. The maximum movement is on the south west side. (See Plan) Five brackets on the south and west moved away from their position. One bracket in the west was completely broken up and few were partially broken .

It was recommended to first support the brackets to prevent them from falling and causing any accident. The beams were then to be supported on both the sides of the brackets, the brackets moved to their original position, and then fixed with mortar or adhesive as needed. The damaged bracket were to be replaced or repaired after assessment on site. Most of the brackets were carved, but whether the same would be done for the new stones, was a decision that was be taken later. Fractured brackets were to be pinned together by using stainless steel threaded bars and epoxy resins. Sometimes were not required. At such times patches of structural glue could be used to join the stones.

Brackets before and after restoration. Some brackets like S2 could not be re-aligned due to positions of other stone elements.

Left
Stonemason adding details to the newly added part of the columns on south at Shiva Level.
(*Photo: KVPT. June 20, 2018.*)

Left Bottom & Center
Images of capitals before and after restoration.

Right Top & Bottom
Column capital were restored but the steel tie was retained in many cases after restoration as precaution.

Damaged column capitals and bases

The column capitals are composed of a flat stone piece embellished with a floral base. The quality of carving in several capitals indicated old repairs. Due to the seismic loading and movements, some of the capitals were damaged. These damages ranged from severe cracks to minor chipping therefore their repair was also to be fashioned as per the damage. However, it was important that the capitals were stabilized in position by ties and props. A few bases had also been damaged but the damages were not very severe.

It was recommended to first support the beams on both the sides of the column, the damaged capital would have to be replaced in part or whole or repaired after assessment on site. Most of the capitals were carved, but whether the same would be done for the new stones, was a decision that was to be taken later. Fractured capitals would have to be pinned together by using stainless steel threaded bars and epoxy resins. Sometimes pins were not required. At such times patches of structural glue could be used to join the stones. Minor damages could be ignored or repaired with matching mortar.

Left Top, Bottom & Center Top, Bottom
Column capitals were restored by pinning, pointing, partial replacement of stone, and where severely damaged or cracked a steel tie was used to hold it together.

Right
Masons Siddhi and Mangal Maharjan pointing column joints after realignment.
(*Photo: KVPT. May 20, 2018.*)

Left Top & Bottom
Top portion of a damages shaft was replaced with a new carved piece of stone.

Center, Right Top & Bottom
The severely damaged shaft S3 , had to be replaced. One old column was found in the material yard which was used as a replacement.

Damaged column shafts

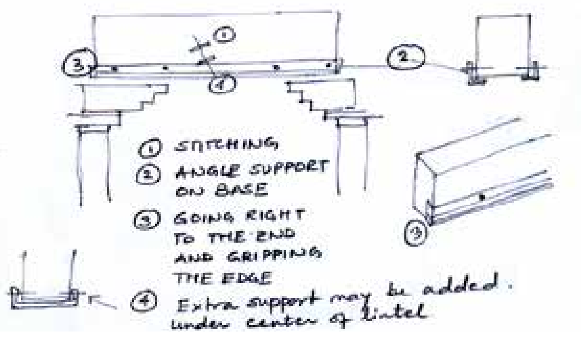
Most of the columns were damaged just below the capital. This damage had also happened during the earlier earthquakes because one could see the old pointing repair. Most of this repair came off during the recent earthquake. Although this damage was non-structural, some of the shafts had been damaged beyond repair. One column had been sliced such that one third of the shaft had fallen off. The top of other columns had been severely damaged.

The three damages would have to be dealt with separately. After supporting the beams, the column shaft had to be gently removed. The severely damaged column had to be replaced since it was incapable to carrying load. The others had to be repaired with new stone pieces such that the cross section of the shaft was not reduced. Stone pieces had to be pinned together by using stainless steel threaded bars and epoxy resins. The sliced column had to be replaced . After the repair, the old and new pieces had to perform as one monolithic whole. The minor damages were to be repaired with matching mortar prepared as per specifications provided.

Cracks in lintel

It was recommended that the building be carefully assessed for cracks after cleaning. Since the cleaning of the stone surface was only to assess the development of damage or cracks, no chemical or invasive mechanical methods was to be used. Only manual cleaning involving dry brushing with a stiff natural bristle brush (not a wire brush) and (non ionic soap) and clean water was to be used to remove organic growth and surface dirt. The cracks were to be monitored for some time to (using crack gauge or stain guage) assess further movement.

Hairline cracks or cracks upto 5mm were to be dealt by filling the void with matching mortar similar in composition to pointing. Some mastic compound could be used for crack filling to allow a little movement, if it was a thermal crack. Reasons for moderate cracks between 5mm and 25mm was to be assessed for local disturbance of building members like rusted dowels or plant growth. They were to be rectified before filling the crack with compatible mortar. There was one major cracks above 25mm in the lintel which needed the attention of an engineer . Only after an assessment of the overall structural system was this to be rectified. Till then, this was be supported by a steel prop below. Luckily only two cracks in the lintel beams could be identified.



Left
Sketch of detail by Conservation Architect.

Center Top & Bottom
Vertical cracks in the lintel beams were carefully monitored and tied with stainless steel pins and stainless steel angels using adhesive and bolb.

Right Top
The team of Engineer Pranam Hora, Stone manson Surya Bahadur taking off the column, repairing and reinstalling the outer column of Shiva level west elevation 3rd column from south. (*Photo: KVPT. May 10 & 11, 2018.*)

Right Middle & Bottom
Engineer Pranam Hora and Stonemason installing the stainless steel angle to the cracked beam. (*Photo: KVPT. June 21, 2018.*)

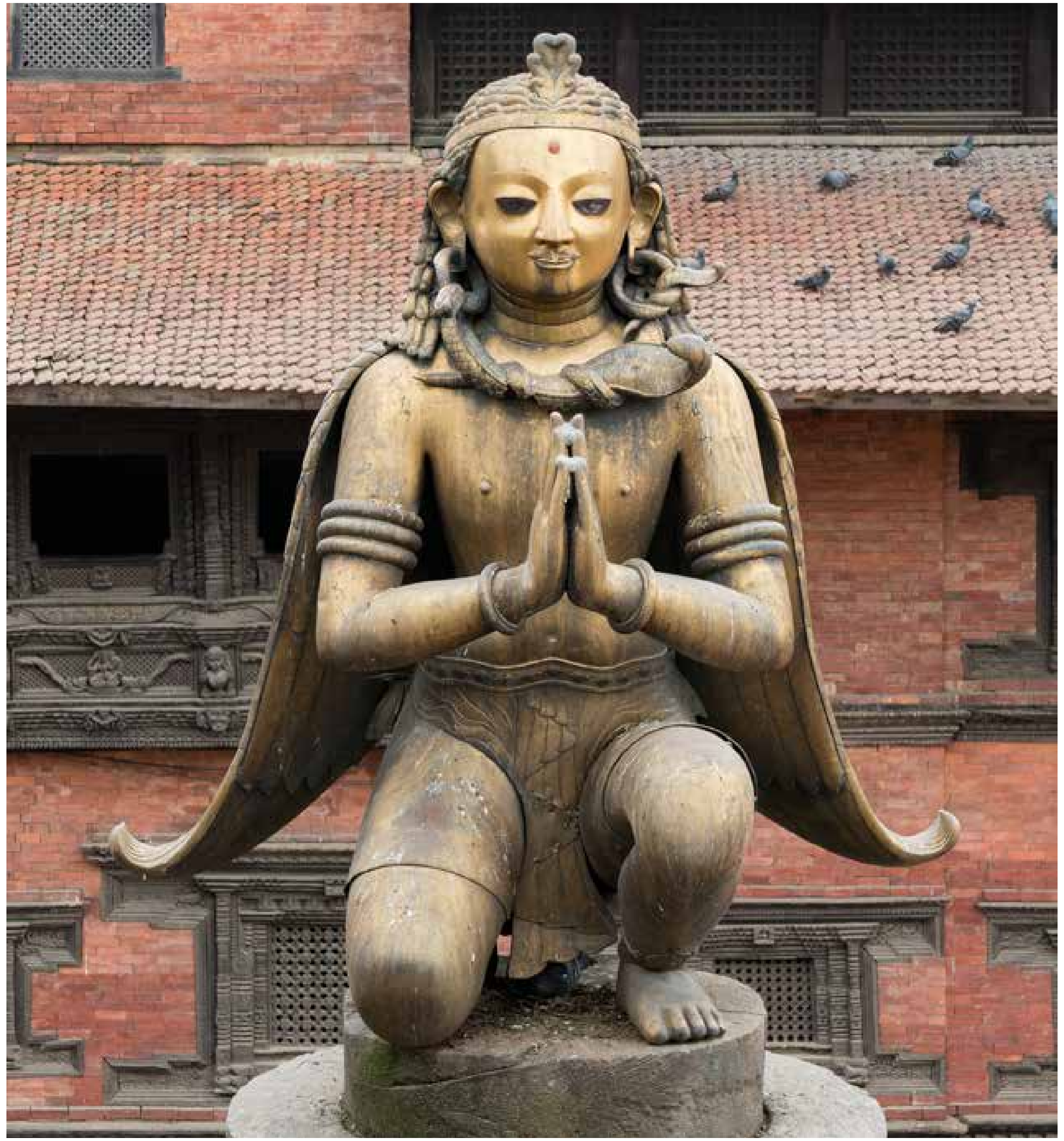
Tin sheet additions

The Shiva level of the temple has eight *chatris*. The areas between them are left open to sky. At some point of time, probably due to penetration of rain water, they had been covered with tin sheets. This had caused some damage to the carved and ornamental stone lintels but none of them was major. These were later removed after restoration and edges repaired. Finally, all the pinnacles, restored by the Austrian team were re-erected.

Left
The first floor Krishna level had an iron railing all around it's perimeter. It may have been useful in preventing damage during earthquake. a similar railing is proposed for the Shiva level.

Center Top & Right Top
Chatris before and after restoration, with and without tin sheet covers.

Center Bottom & Right Bottom
Blacksmith Lal Bahadur and Bala Ram Nakarmi repairing the existing north west corner staircase iron railing and installing them on its original location.
(*Photo: KVPT. June 21, 2018.*)



Close up view of the Garuda on the pilllar
(Photograph by Ashish Rajbansh.)

Chapter 6:

Material Conservation-Restoration

Martina Haselberger, Katharina Fuchs, Gabriela Krist

Introduction

The geometrical shaped stone temple of Krishna, so-called Krishna Mandir, constitutes one of the most important monuments comprising the architectural ensemble at the Patan Durbar Square. It can be dated to 1637 and is constructed in the typical Hindu temple style, called *shikhara*, which entered Nepal in the 17th century.[1] Designed with three storeys, the whole temple is built from small stone blocks and embellished with 21 fire-gilded pinnacles, so-called *gajuras*, fitted over the stone *shikharas*.The roof top is bell shaped and also capped with a pinnacle, which is surrounded by four lions on the edges, four deities and a flagpole.[3]

In 2016 the team of the Institute of Conservation at the University of Applied Arts Vienna was first consulted and asked for professional support with regard to the conservation of the stone elements and the joints. Severe cracks were visible in the stone blocks at the top floor. Measurements with an ultrasound device failed to yield meaningful results as the cracks in the stone and the gaps between stone blocks were too wide to be bridged by the ultrasonic waves.

Furthermore, it was assumed that particularly the joints in the roof top area were partly open or damaged as moisture penetration and seepage of water could be observed on the ceiling of the second floor level. In addition, the cement-based mortar, which was used for re-pointing of almost all joints in the framework of a previous restoration, seemed to be too dense and thus harmful for the surrounding stone.

The scaffolding, which was erected during the static restoration work at the temple after the earthquake of 2015, provided the unique opportunity for the conservators to survey the whole outer shell of the monument and to access the roof area. Based on the knowledge gained from the condition survey on site, results of scientific investigations of samples taken (mainly existing mortars) and test series, a concept for repointing was elaborated and an adequate mortar recipe was developed[4]. During the working campaign in February 2018[5], re-pointing was carried out at the rooftop area of Krishna Mandir by stone conservators together with local masons and stone masons (Mapping 1). Simultaneously the fire-gilded metal embellishments were treated by the team of the Institute of Conservation together with local coppersmiths. Both was accomplished in close collaboration with the Kathmandu Valley Preservation Trust (KVPT).

Materials and Construction

The top area of Krishna Mandir mainly consists of blocks made of the highly porous, capillary-active sandstone, which can also be found at the Stone Gates of the Degutaleju Temple or the Bhandarkhal Tank Pavilion in the palace garden.[6] With regard to its grain size (roughly 50 µm) and composition it can be characterized as fine-grained siliceous, sedimentary stone with high content of feldspar and clay. The stone is ochre-coloured, whereby the weathered surface appears more greyish. The single stone blocks were partly connected with iron clamps in the course of a former restoration, whereby the total number of inserted clamps and their exact location were not documented properly. Beside the sandstone a metamorphic stone variety was used for load-bearing and static components

1Rajtiwari, S.,Temples of the Nepal Valley, Kathmandu 2009, p. 114; Bajracharya, B. / Sharma, S. / Bakshi, S. (Ed.), Cultural History of Nepal, Delhi 1993, p. 78.

2Lalitpur Heritage Group (Ed.), Shri Krishna Mandir Conservation Project, October 1997 – August 1998, unpublished report, Lalitpur 1998, p. 34.

3Bajracharya/ Sharma/ Bakshi 1993, p. 22.

4 See Widtmann, B., Krishna Mandir at the Patan Durbar Square. Concept for repointing, unpublished report, Institute of Conservation, University of Applied Arts Vienna, Vienna 2018.

5 The work campaign was kindly funded by the Austrian Development Agency (ADA), the Federal Chancellery of Austria (BKA), the Federal Ministry of Europe, Integration and Foreign Affairs of Austria (BMEIA), the Eurasia-Pacific-Uninet (EPU) and the University of Applied Arts Vienna.

6 Fuchs, K., Bitumen Coating on Stone, a Nepalese Problem? The Conservation of Two Stone Relief Gates at theNasal Chowk, Patan Royal Palace, unpolished Pre-Thesis, Institute of Conservation, University of Applied Arts Vienna, Vienna 2013;Leiner, S., Der Pavillon am Bhandarkkal-Tank, PalastkomplexPatan, Nepal, unveröffentlichtesVordiplom, InstitutfürKonservierung und Restaurierung, UniversitätfürangewandteKunst Wien, Wien 2010.

Facing Page
Fig.34: Condition after conservation.

7 Scientific investigations of the samples were carried out by student Benjamin Widtmann, Institute of Conservation, together with Prof. Johannes Weber, Conservation Science, Institute of Art and Technology, University of Applied Arts Vienna, in 2017/18. See also Widtmann 2018.

on the lower floors.
Existing joint mortars at the top area were characterized by visual inspections combined with scientific analyses of taken samples using polarizing microscopy and scanning electron microscopy (SEM) in the laboratories of the University of Applied Arts in Vienna[7]. At least four types of mortars could be determined. The first and probably most recently applied one is a very hard greyish cement-based mortar with an adequate amount of aggregates (coarse quartz and alkali feldspar), hereby named type A (fig.1).The used cement is comparable

with Portland cements used in Europe during the interwar period. The mortar was apparently appliednot only in most joints but also as a layer above weathered surfaces. Due to its density and capillary-inactivity, the cement mortar allows the stone to remain wet for a longer period which particularly resulted in sanding and disintegration. In some areas the mortar is firmly connected to the stone structure.The second mortar, type B, is not as hard as the above mentioned, but also too dense for the underlying stone. Its colour is greyish but slightly brighter than type A. This mortar has also brick dust as filler.

Underneath these cement-based mortars, a brick dust-lime mortar, type C, could be partly detected (fig.2). The big lime lumps, detectable by microscopic examination, indicate a short time of slaking. The aggregate contains a high amount of quartz and feldspar in an adequate relation to the binder. The mortar was probably applied as kind of buffer between the stone and the dense and hard cement mortar or was used to level the uneven

Left
Fig. 1: Mortar Type A.

Right
Fig. 4: Substructure and mounting of the metal pinnacle.

stone surface.
In some areas, remnants of another highly porous, white to greyish mortar, type D, were detected. With regard to strength and structure it is comparable to type C, but contains no brick dust as filler. Instead, mainly limestone, dolomite, glimmer and a bit quartz were used as aggregates, whereby the amount of those is rather small compared to the concentration of binder, which was identified as lime.

The presence of different joint mortars, which were documented by the Institute of Conservation in the course of the condition survey, supports the assumption, that there had been previous repair and restoration work at Krishna Mandir. Nevertheless, only little record and documentation on past interventions, mainly carried out in the 20th century, is available to date[8].

Beside the mortars, it was also possible to detect resin, so-called silay[9], inside the joints, which was originally used for stone bedding.

The metal pinnacles distributed over the whole temple are made of fire-gilded copper plates. They consist of multiple pieces similar in shape and size with a height of around 1 m (fig.3), whereby only the top pinnacle

is considerably larger. For their mounting lock chains, hooked to the pinnacle's head and anchored at the base, iron ring clamps and wooden components were used (fig.4).

Condition

The roof top of Krishna Mandir shows no covering against rain and/or protection against pigeons. Thus the stone blocks and joints as well as metal pinnacles are exposed to direct weathering and accumulation of bird droppings, which accelerate deterioration.

At the time of the survey all surfaces were covered with partly loose deposits of dust and dirt as well as pigeons droppings (fig.5). Several joints were open and still available mortar was partly cracked at the flanks to the surrounding stone or internally (fig.6). Both enabled water infiltration. The extensively applied cement-based joint mortars(type A and type B) were not suitable for the surrounding stone (too dense and stiff) and resulted in accelerated deterioration of the stone material, like sanding and scaling (figs.7 and 8). Moreover the mortar was partly applied as thin layer over the stone surface, which not only altered the shape of the surface but caused waterlogging in the stone underneath and disintegration and sanding. Corroded iron clamps inside the structure caused cracks in the stone. Even some missing stone blocks could be detected (fig.9). In the open joints and gaps accumulated dirt provided a sound base for plant growth.

8 Lalitpur Heritage Group 1998.

9 KVPT, Nepal PatanDarbar. Earthquake Response Campaign. Documentation of Work to Date, September 2016, Kathmandu, 2016, p. 67.

Left
Each of the 20 pinnacles were taken apart and were first cleaned with brush to remove loose particles then cleaned using citric acid diluted with water.
(*Photo: KVPT. Feb 18, 2018.*)

Center
Fig.3: Single pieces of the dismantled metal pinnacle.

Right Top
Fig.9: Missing stone block, condition before conservation.

Left Top
Fig.2: Mortar Type C.

Left Bottom
Fig.5: Loose deposits, dust, dirt and pigeon droppings, condition before conservation.

Right Top
Fig.7: Cracked stone, condition before conservation.

Right Bottom
Fig.8: Sanding and scaling of stone, condition before conservation.

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Left
Fig.6: Old joint mortar, partly cracked or missing, condition before conservation.

Right
Fig.10: Conditon of the metal pinnacle before conservation.

On the surfaces of the pinnacles green corrosion occurred. Furthermore the gilding has been entirely worn off on some areas. Some pinnacles showed deformations, dents and partly loose elements (fig.10). Several cracks and small holes could be detected in the fire-gilded copper sheets. The mounting construction made up of iron was heavily corroded and the wooden parts were rotted.

Aim and Concept of the Restoration

The primary aim of the restoration was to achieve a closed joint system at Krishna Mandir in order to prevent water infiltration and preserve the stone construction. Thus, all cracked, damaged or insufficient joint mortars as well as those made of inadequate mortar should be removed and the joints subsequently repointed. For this purpose an appropriate joint mortar[10] should be used, which causes no harm to the stone and is adjusted to the

physical, chemical and optical properties of the stone material, which was subject of previous research at the Institute of Conservation[11].

The mortar should primarily rely on locally available materials, which allows immediate purchase and continuative use in the future. Further,it should include hydraulic components to improve curing process, adhesion to the surrounding stone and durability under weathering and harsh climatic conditions[12]. In order to verify components and ratio of binder to aggregate, test series were done, whereby recommendations for suitable mortars by Fuchs (2014) were exploited. Tested components included the natural hydraulic lime NHL 3.5 (LaFarge) available in Nepal[13], brick dust and local sands with mainly contain quartz and feldspar. The different mortars were subsequently evaluated with regard to hardness, colour and workability.

With regard to the metal pinnacles the conservation aims at achieving a secured condition as well as a well-groomed and homogenous appearance. On the one hand, a stable and safe mounting should be ensured, on the other hand, decay factors (corrosion, cracks resulting in water infiltration) that cause damage to original substance should be eliminated. The concept for conservation is based on a test treatment of one pinnacle of Krishna Mandir carried out in 2017. Further, knowledge and experience gained in previous metal conservation projects in Patan could be used and incorporated in the project[14].

10 During the winter semester of 2017/18 student Benjamin Widtmann was elaborating a proper mortar recipe using the local materials in Nepal. See Widtmann 2018.

11 Stone analyses were already carried out during earlier conservation campaigns of the Institute of Conservation, University of Applied Arts Vienna, and are documented inFuchs2013 or in Leiner 2010.

12 As it is uncertain, when the roof top area can be maintained or checked in the future, the use of a durable mortar is crucial.

13 A sample of the NHL was analysed and compared with a product sample of the respective commercial producer in France to determine possible deviations in composition. Analyses were carried out with Fourier-Transform-Infrared spectroscopy in Attenuated Total Reflection (FTIR-ATR) by Dr. Marta Anghelone, Institute of Conservation, University of Applied Arts Vienna, in 2018.It could be concluded that both samples are comparable, although the Nepalese NHL is characterized by a less homogeneous composition.

14 Compare unpublished reports of the conservation campaigns 2010 to 2017 as well as: Krist, G., Haselberger, M., Milchin, M., The Pillar of King YoganarendaMalla at the Patan Durbar Square, Conservation of the stone pillar and the fire-gilded sculpture and re-erection, unpublished working report, 2017; Wagner, T., The Golden Doorway Ensemble. Patan Royal Palace Complex, Nepal. Between the Austrian Conservation Approach and Nepali Craftstradition, unpublished Pre-Thesis, Institute of Conservation, University of Applied Arts Vienna, Vienna 2013; Treml, M., The Throne of the Patan Kings in the Patan Museum, unpublished pre-diploma thesis, University of Applied Arts Vienna, Vienna 2018.

Conservation Treatments

Conservation of the Stone and Repointing of the Joints
Before and during work, loose deposits such as sand, soiling and branches had to be constantly removed. Thick layers of dust, dirt and pigeon droppings were removed with brushes while rinsing with water.

Damaged or inadequate joint mortars were removed mechanically with hammer and chisel to a depth at least twice the joint width (figs. 11 and 12). Further, thin layers of mortar, which were applied over the stone surfaces were reduced carefully.

Several original stone blocks were in rather bad condition showing cracks, fractures, delamination and detached scales. With regard to the risk, that they may fall down and the unknown date of re-access to the roof area in the future, it was decided to replace these heavily damaged blocks in order to avoid harm to humans by falling parts (see mappings 2-5). The local stone mason was assigned to prepare tight-fitting stone indents (figs.13 and 14). These were just fixed with a few spots of epoxy resin (Akepox 2010, Akemi), further reinforcement (e.g. pins, clamps) was not considered necessary to keep them in place (fig.15). After hardening of the resin, the joints around the new stone blocks were repointed.

Corroded iron clamps, which were detected (see mappings 6 and 7) during working process, were treated accordingly. Measures included mechanical removal of corrosion and application of a protective layer of lead oxide (red lead, minium) to inhibit future corrosion (figs.16-19). Subsequently, mortar was applied above the clamps. The complete removal of the iron clamps was not possible without damaging the original stone substance.

Left Top
Fig.11: Mechanical removal of the joint mortar.

Center Top
Fig.12: Mechanical removal of the joint mortar.

Right Top
Fig.13: Creating of new stone indents.

Right Bottom
Fig.15: Gluing of stone indents.

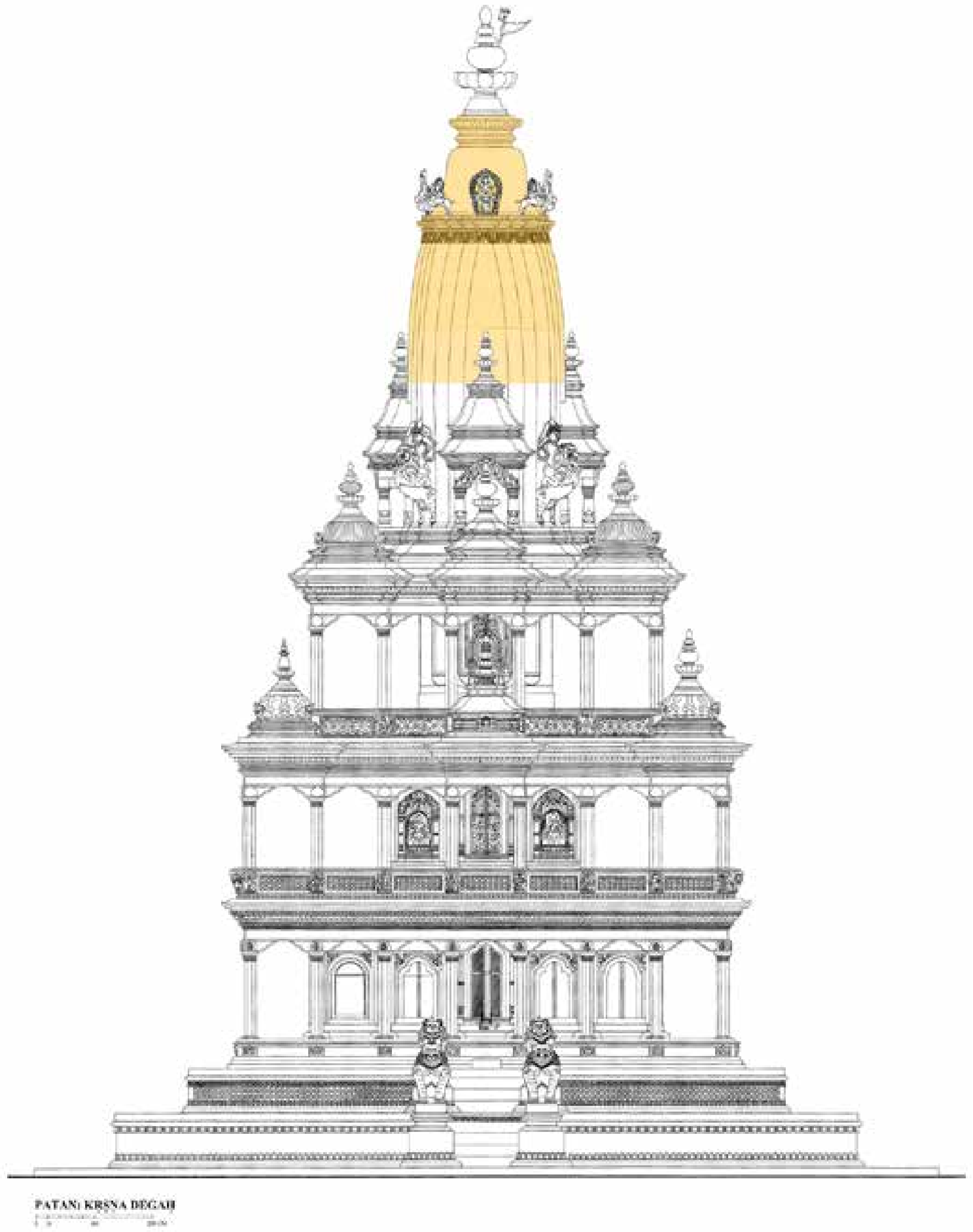
Left Top
Fig.14: New stone indent.

Left Middle
Fig.16: Corroded clamp, condition before treatment.

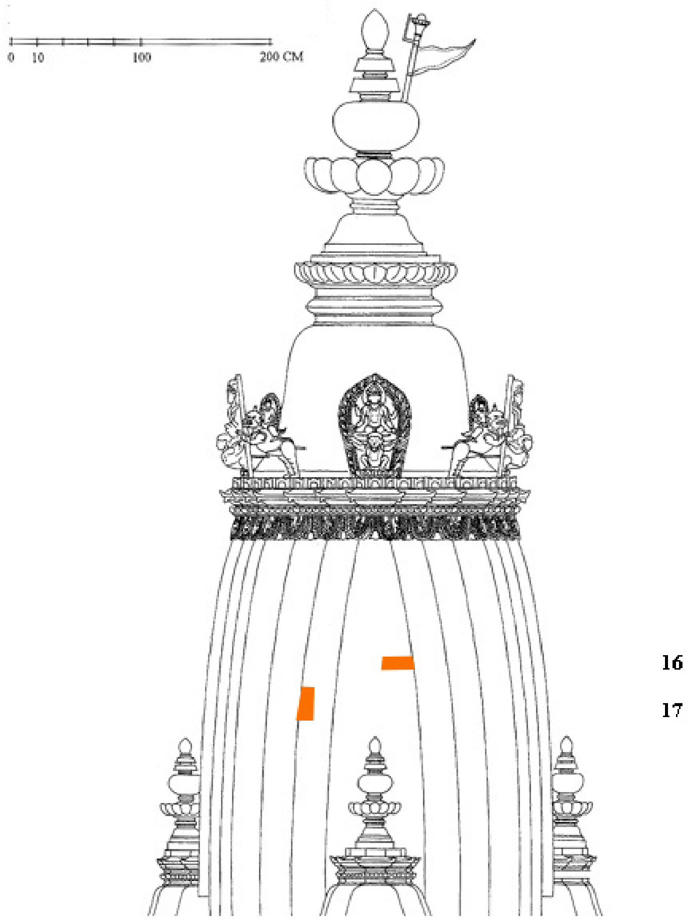
Right Top
Fig.17: Mechanical removal of corrosion on the clamp.

Right Bottom
Fig.18: Application of anti-corrosion paint.

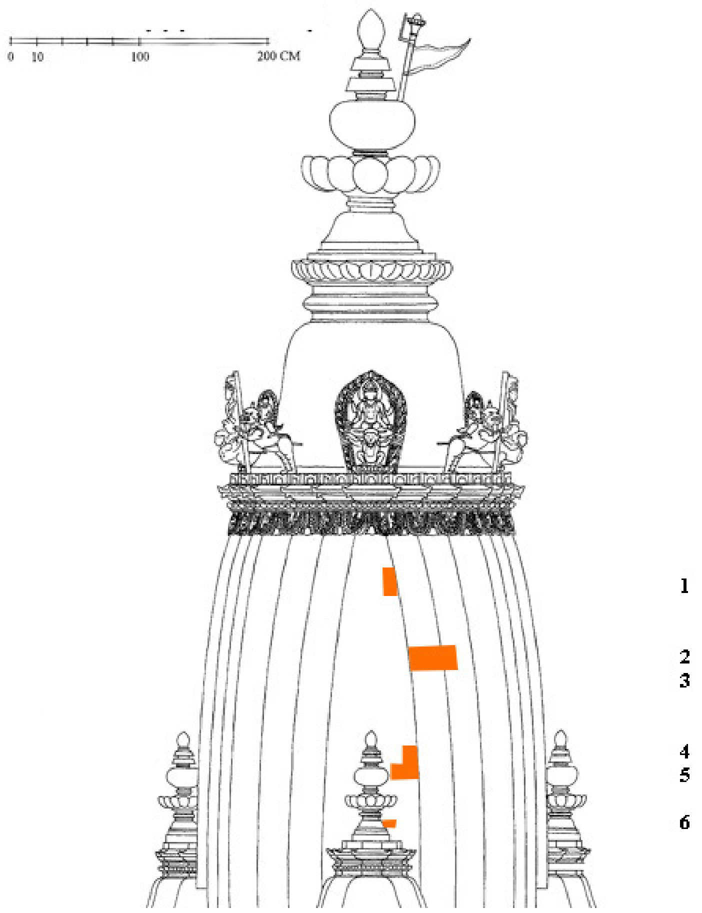
Left Bottom
Fig.19: Iron clamp, condition after treatment.



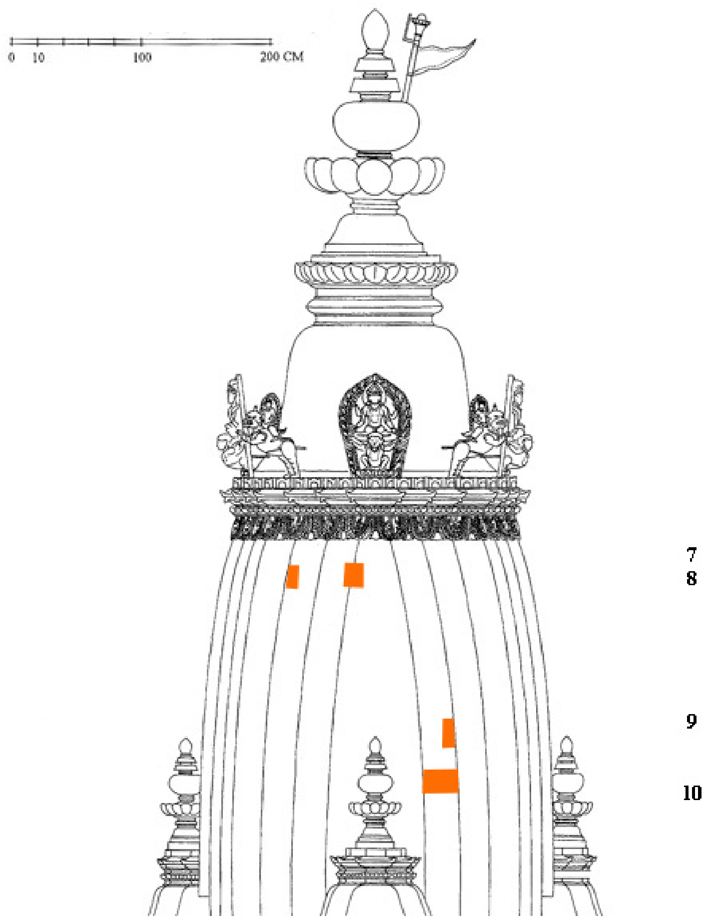
Mapping 1: Front elevation of the Krishna Mandir, treated roof area is marked in yellow, (State February 2018) drawing by KVPT, modified by Katharina Fuchs.



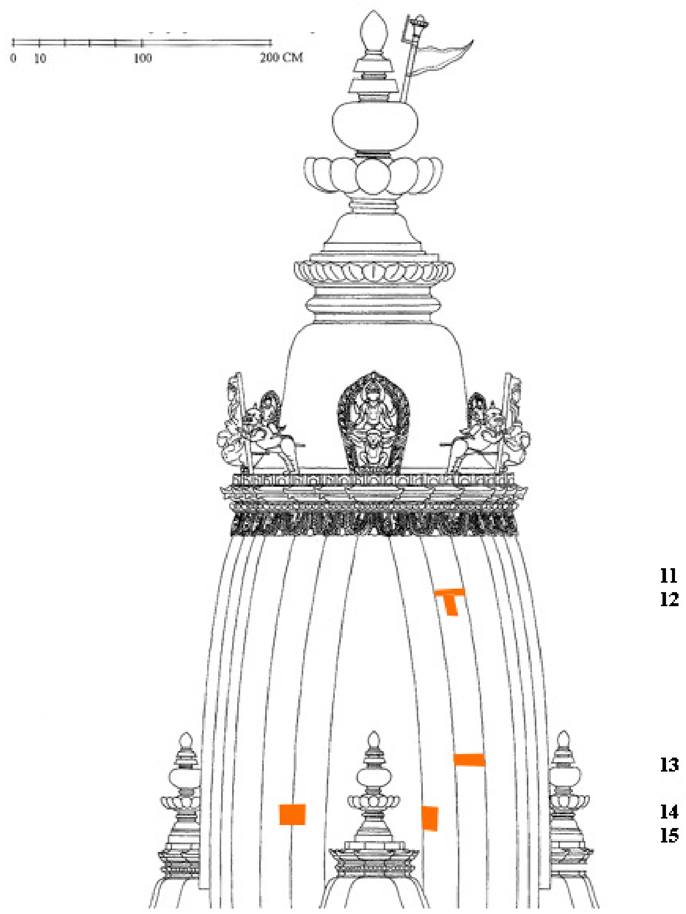
Mapping 2: North -mapping of new stone blocks, drawings by KVPT, modified by Katharina Fuchs.



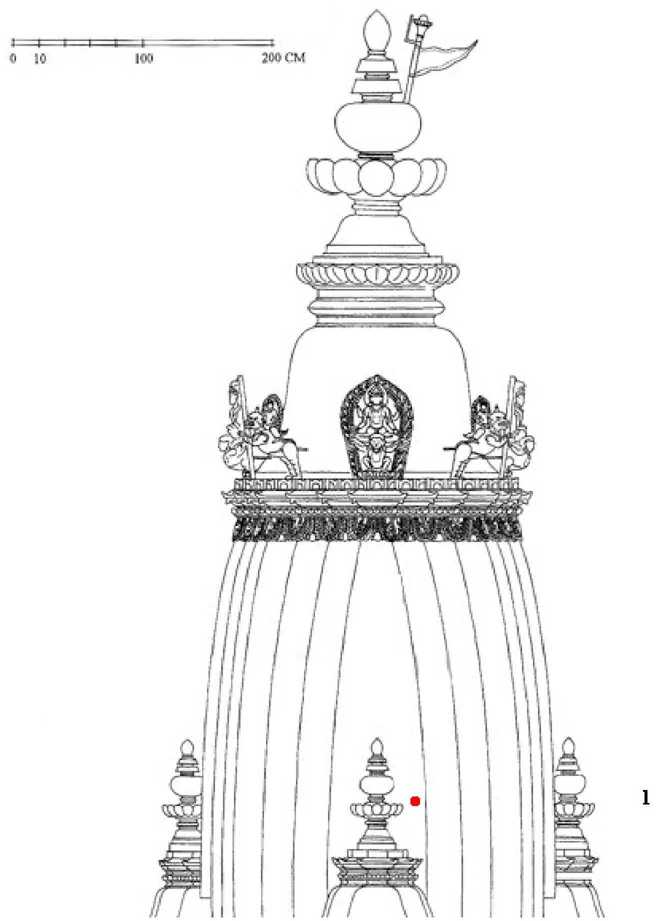
Mapping 3: East-mapping of new stone blocks, drawings by KVPT, modified by Katharina Fuchs.



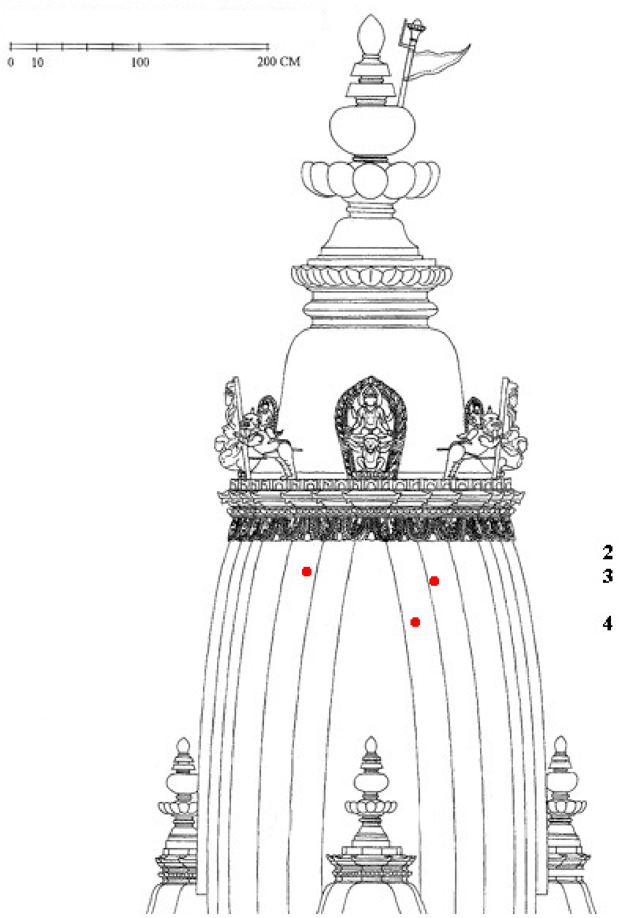
Mapping 4: South -mapping of new stone blocks, drawings by KVPT, modified by Katharina Fuchs.



Mapping 5: West-mapping of new stone blocks, drawings by KVPT, modified by Katharina Fuchs.



Mapping 6: East -Mapping of the found iron clamp, drawing by KVPT, modified by Katharina Fuchs.



Mapping 7: West-Mapping of the found iron clamp, drawing by KVPT, modified by Katharina Fuchs.

Before the joints were re-pointed, they were cleaned with brushes and old mortar residues were removed with spatula. Further, the surrounding stone and the joints themselves were pre-wetted with water to ensure an optimal curing and good adhesion of the lime-mortar. The used mortar consists of natural hydraulic lime (NHL 3.5, LaFarge) and locally available sand, whereby two different ratios were used for small and big joints[15]. Large gaps between stones were pre-filled with crushed stones, which acts as bigger aggregate, to avoid cracking of the joint mortar while drying (fig.20). For a better adhesion, especially at smaller joints, a small amount of acrylic resin (Primal ® SF 016, Deffner&Johann) diluted in water (5%) was added to the freshly mixed joint mortar.

Mortar had been applied tightly in the open joints and above level of the surrounding stone (figs.21 and 22). After a half day or even a day, depending on how thick the mortar was applied, the mortar surface was scratched off with the spatula to the stone level. That way the mortar gets a more porous and permeable surface and the accumulated lime-rich layer on top is removed. Further, this post processing of the joint mortar ensures controlled water drain and avoids accumulation of water in cavities in the future. Of utmost importance for the curing was to ensure that the mortar remains moist not wet for some time after application. For this purpose water got sprinkled almost every 20 minutes the first two days. Afterwards, the joints were moistened every 30 to 60 minutes on the third and fourth day. During night time the whole surface, which was treated during the day, was first pre-wetted with water and then wrapped with a moist fabric and a plastic foil to keep the surface moist for a longer period (fig.23).

Finally, the surrounding stone surfaces were mechanically cleaned with hard brushes and spatulas to remove remnants of lime and mortar (fig.24).

15 Fine mortar recipe for small joints: 1 vol. part natural hydraulic lime + 3 vol. parts sieved sand. Coarse mortar recipe for big joints: 1 vol. part natural hydraulic lime + 4 vol. parts sand.

Center Bottom
Fig.20: Bigger joints are filled with small stones before pointing.

Left Top
Fig.21: Pointing of joints.

Right Bottom
Fig.22: Pointing of joins.

Conservation of the Metal Pinnacles

In a first step the small metal pinnacles were dismantled together with their substructures to enable easier handling and treatment, while the main pinnacle, the deities and the flagpole on top were treated on site. The single elements of the pinnacles were numbered according to a previously drafted plan to assign each piece to its right position after conservation.

The fire-gilded metal surfaces were dry and wet cleaned to remove any dust and dirt layers. In addition, corrosion layers were reduced mechanically and by use of a complexing agent (figs.25-27). Hereby citric acid diluted in water was applied, which already proved effective and suitable in the given environment. Cracks and holes in the copper sheets were closed with epoxy resin (Akepox 2010, Akemi). Corrosion on the iron substructures was removed mechanically and an anti-corrosion coating (red lead, minium) applied on their surfaces (fig.28). Rotten remnants of wooden substructures were replaced with newly created iron elements done by a local blacksmith. Afterward the pinnacles were re-assembled again on the temple.

Left Top
Fig.23: Wrapping of newly pointed joints over night to keep them moist.

Left Bottom
Fig.24: Final cleaning of surrounding stone surfaces after pointing.

Center Top
Fig.25: Mechanical cleaning of fire-gilded metal surfaces.

Center Bottom
Fig.26: Wet cleaning of fire-gilded metal surfaces by use of water and complexing agent.

Right Top
Fig.27: Detail of the flagpole before (right) and after cleaning (left).

Left Top
Fig.29: Condition before conservation.

Right Top
Fig.28: Application of anti-corrosion paint on iron substructures.

Right Bottom
Fig.30: Condition after conservation and re-pointing of joints.

Conclusion

In the framework of the working campaign in February 2018, conservation work at the roof area of Krishna Mandir could be successfully completed by staff and students of the Institute of Conservation together with local craftsmen.The collaboration with the KVPT throughout the whole project was decisive to provide the necessary infrastructure and required materials and tools on site.

The major objective was to restore an appropriate joint network, again fulfilling its protective function for the stone material. Formerly applied joint mortar (cement-based) was unsuitable to the surrounding stone and caused damage and loss of the original substance. Thus, inappropriate as well as damaged joint mortars were removed and joint repointed with a tested mortar based on natural hydraulic lime and adjusted to the chemical, physical and optical properties of the stone. Severely damaged stone blocks were replaced with fitting stone indents prepared by a local stone mason (figs.30-32).The fire-gilded metal embellishments (pinnacles, deities and flagpole), present themselves after conservation again in a well preserved condition (figs.33 and 34). Their optical appearance could be unified to a very satisfactory level and their mounting improved.Investigation, scientific analysis, test series and test treatments in the run-up to the working campaign built not only the scientific base for the implemented conservation measures but ensured a smooth work flow. The methodological conservation approach and developed recipes can be applied in the ongoing conservation work at Krishna Mandir and in comparable tasks at surroundings monuments.

Left
Fig 33: Deity at roof area after conservation

Center
Fig.31: Condition after conservation and re-pointing of joints.

Right Top
Fig.32: Condition after conservation.

Left
Metal worker Babu Ratna Maharjan and Binod Maharjan cleaning the parasols (*chatra*) before they were gilded.
(*Photo: KVPT. Mar 25. 2018.*)

Right
Fig. 1: Garuda Pillar infront of Krishna Mandir.

1.Kaipf, L., The Pillar of YoganarendraMalla. Condition Survey, Conservation treatment and Re-erection, unpublished Pre-Thesis at the Institute of Conservation, University of Applied Arts Vienna, Vienna 2017, p. 17

2.Bühnemann, G., Royal Likenesses on Pillars, in: OCHSPA (Ed.), The Cultural Heritage of Nepal, before, during and after the 2015 Earthquakes. Current and Future Challenges, [ISBN 978-9937-0-3203-2], p. 53-57

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Conservation-Restoration of Garuda Pillar

The tradition of erecting stone pillars can be traced back to the sacred pillars widely worshiped all over the world in Neolithic times.[1] On the Indian subcontinent, particularly Garuḍa pillars have a long tradition, with the oldest surviving pillars dating back to the 5th century CE.[2] The pillar of Garuda (fig. 1)on the Patan Durbar Square (fig. 2) comprises not only an important element of Patan's architectural ensemble but is part of Kathmandu Valley's UNESCO World Heritage Property. Beside its cultural importance it also represents an important living heritage.

Garuda pillars are usually positioned in front of Vishnu temples as Garuda is the mount of god Vishnu. In addition, Garuda is considered the king of birds and Garuda together with lord Vishnu legitimize kingship. Therefore, Garuda pillars are mostly located not only in front of the entrance of the Vishnu temple but also in front of the entrance of Royal Palaces, as it is the case at the Patan Durbar Square.

Materials and Construction

The fire-gilded metal sculpture of Garuda, consisting of several parts and two metal rings (fig. 3), is situated on a stone pillar. Garudais depicted as a humanoide bird in an almost kneeling position, a depiction that is – in contrast to Indian Garudas – common in Nepal.[3]

The stone pillar consists of four parts (excluding the square base). On the lowest one, the column shaft,

and two further elements, which form the lotus flower, are placed. All of these are made of calcite schist[4] . The plinth of Garuda on top is made of fine grained silicate sandstone. Between the column and the first lotus flower element a metal ring was applied for better stability. Another, thinner, metal ring was applied probably later,around the plinth in order to stabilize the already weathered stone.

Condition

At the time of the survey the surfaces were covered with loose deposits of dust and dirt and with pigeons' droppings. Remnants of Tikka paste, wax stains as well as labels and leaflets could be detected particularly in the lower area of the pillar. Here, the stone surface was also partly impaired by different kind of graffiti and scratches. Nevertheless, in general the condition of the stone material itself could be considered as rather good. In the area close to the ground, sometimes thin blackish crusts can be found.

On the surfaces of the metal sculpture corrosion products were visible. Furthermore, the gilding has been reduced on some areas. One of the iron rings was already corroded due to direct exposure to weathering, the climatic conditions in Nepal (wet and dry periods) and the high pollution within the city.

Aim and Concept of the Conservation

The primary aim of the conservation was to achieve a secured and well-groomed, homogenous appearance of the whole pillar ensemble (stone elements and metal sculpture). Therefore, the treatments for the stone elements of the pillar included cleaning, reducing deposits and pointing open joints as well as sealing cracks. For the metal sculpture the conservation aimed, on the one hand, to ensure a stable and safe mounting and, on the other hand, to significantly slow down or eliminate decay factors (corrosion, cracks resulting in water infiltration) which cause damage to original substance.[5]

4.Kaipf, L., The Pillar of YoganarendraMalla. Condition Survey, Conservation treatment and Re-erection, unpublished Pre-Thesis at the Institute of Conservation, University of Applied Arts Vienna, Vienna 2017, pp. 9

5.The concept for conservation was based on experiences gained in earlier conservation work carried out at the Patan Royal Palace and Durbar Square since 2010.Compare unpublished reports of the conservation campaigns 2010 to 2017 as well as: Krist, G., Haselberger, M., Milchin, M., The Pillar of King YoganarendaMalla at the Patan Durbar Square, Conservation of the stone pillar and the fire-gilded sculpture and re-erection, unpublished working report, 2017; Wagner, T., The Golden Doorway Ensemble. Patan Royal Palace Complex, Nepal. Between the Austrian Conservation Approach and Nepali Craftstradition, unpublished Pre-Thesis, Institute of Conservation, University of Applied Arts Vienna, Vienna 2013; Treml, M., The Throne of the Patan Kings in the Patan Museum, unpublished pre-diploma thesis, University of Applied Arts Vienna, Vienna 2018.

Left
Fig. 2: Garuda sculpture before cleaning.

Conservation Treatments
Stone Conservation

The cleaning of the stone elements of the pillar started with a dry cleaning. A mechanical removal of loose deposits was done with brushes and spatulas and was followed by a chemical- mechanical cleaning with a tenside-solution and brushes. At the base level most deposits were of anthropogenic origin, probably resulting from worship and sacrificial offerings. They were reduced with acetone-soaked cotton pads and spatulas. Afterwards all surfaces were rinsed with water to remove any remains.

In order to avoid water infiltration in the upper part of the pillar, open joints and small cracks were pointed and closed with a mortar based on natural hydraulic lime (NHL 3.5, LaFarge) and different sand.[6] For wider cracks, sand with a slightly different grain size distribution was used for the pointing mortar.[7]

Left
Fig.3: Open crack at the plinth, visible microbiological colonization

Right
Fig.4: Cleaned surfaces, crack with filled injection grout at the plinth of Garuda

6.Pointing mortar: 3 vol. parts sand (1 vol. part yellowish bore dust of local stone + 2 vol. parts black marble sand (SchwarzesMarmormehl 0 – 0,6 mm; Kremer Pigmente)) and 1 vol. part binding media (natural hydraulic lime, NHL 3.5 LaFarge)

7.1 vol. part bore dust of local stone + 1 vol. part black marble sand (SchwarzesMarmormehl 0 – 0,6 mm; Kremer Pigmente) + 1 vol. part black marble sand (SchwarzerMarmor, Mehl-Gries, 0,7 – 1,2 mm; Kremer Pigmente).

The crack at the plinth (figs. 3 and 4) was additionally pre-filled with pure natural hydraulic lime mixed with water to an injectable consistency before the joint mortar was applied.

In general, the joint mortar was applied above level of the surrounding stone and scratched off to the stone level after some time of curing. In this way the mortar gets a more porous and permeable surface and the accumulated lime-rich layer is removed. Optimal curing was ensured by pre-wetting of the surrounding stone and the joints themselves and moistening of the applied joint mortar for four days (fig. 5).

Finally, the surrounding stone surfaces were mechanically cleaned with hard brushes and spatulas to remove remnants of mortar. Some joints were additionally retouched, whereby dust particles and fine sand grains mixed with water were applied directly in aqua sporca. After drying of the retouching acrylic resin (Primal ® SF 016, Deffner&Johann) diluted in water (5%) was applied on the retouched area for a better protection against weathering.

Metal Conservation

The fire-gilded metal sculpture of Garuda was dry cleaned in a first step to remove loose deposits, dust and dirt. Then a wet cleaning with a tenside-solution and brushes was done (figs.6 and 7). Corrosion products were removed mechanically. Cracks and holes in the metal surface were closed with epoxy resin (Akepox 2010, Akemi) to avoid water infiltration.The corrosion on the metal rings was mechanically reduced with a fine wire brush.

Conclusion

The conservation work at the Garuḍa pillar could be successfully completed by senior and junior conservators of the Institute of Conservation together with local craftsmen. The collaboration with the KVPT throughout the whole project was decisive to provide the necessary infrastructure and required materials on site.

The major objective was to preserve and clean the surface of the stone pillar as well as the metal sculpture. Therefore, different cleaning methods were used and small preservation measures applied such as securing of loose parts on metal as well as in some stone areas. Open joints between the single stone blocks were closed to avoid water infiltration.

The optical appearance could be unified to a very satisfactory level.

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Left
Fig.5: Detail of re-pointed joint

Right Top
Fig.6: Detail of Garuda before cleaning

Right Bottom
Fig.7: Detail of Garuda after cleaning

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